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JOURNAL OF PALEONTOLOGY

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VOLUME 16 · MAY, 1942 · NUMBER 3

CONODONT ASSEMBLAGES FROM THE HEATH FORMATION, MONTANA

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ABSTRACT—Conodont assemblages and individuals from the Heath shales of Montana are described. All of the individual conodonts are considered to have been part of some complex conodont assemblage. Two new conodont genera, *Lochriea* and *Lewistownella*, are established on the basis of assemblages. The individual conodonts within the assemblage are referred to by reducing a "form generic" name such as *Hindeodella* to a common noun, hindeodell. A perfect assemblage consisted of a battery of teeth arranged into approximately four parts, depending upon the number of kinds of teeth. It is suggested that previously established methods of classifying individual conodonts be continued.

CONODONT assemblages were first described by Schmidt (1934) and Scott (1934), both of whom interpreted them as representing the remains of a single animal. Some of these assemblages included such diverse forms as *Spathognathodus*, *Prioniodus*, and *Hindeodella*. The discovery of the assemblages by the above workers was made almost simultaneously in widely separated areas, and the conclusion was reached by both that they represent natural groups of teeth from an individual animal and did not represent accidental accumulations or coprolitic material. However, their interpretation of the zoological affinities of conodonts differed greatly. Schmidt assigned them to fishes, and Scott concluded that they belonged to annelids. Regardless of the differences in interpretation as to the zoological affinities of the conodonts, the most important point is that the assemblages were recognized by both workers as remains of a single animal even though possessing several different architecturally designed teeth.

Demanet (1939) reports the occurrence of conodonts with *Coelacanthus lepturus* Agassiz from the Carboniferous of Belgium and says that the conodonts are *in situ*. Unfortunately, the sketches of this interesting specimen leave much to be desired. The figures do not particularly suggest conodonts either in size or shape and, judging from the figures, cannot be assigned to *Synprioniodina simplex* Pander or any other known conodont.

This paper is primarily for the purpose of illustrating additional assemblages found since 1934 and to cover more fully the conodont fauna of the lower shales of the Heath formation of Montana. The writer wishes to express his thanks to Dr. C. Wythe Cooke for many constructive criticisms. Special thanks are also due to Allen F. Agnew, University of Illinois, for aid in sorting and photography.

CLASSIFICATION

The general problem of classifying many groups of micro-organic structures is one of the most vexing problems confronting the

science of paleontology. Many schemes of classification have been proposed, a "military classification" (Croneis, 1940), "form genus," "organ genus," "collective groups," "sections," and many others. So many terms have been proposed and used that the problem is acute and will retard some phases of research until a clear-cut decision has been rendered by some rules committee that all can follow.

Everyone wishes to follow a binominal system, but to classify certain isolated parts as genera and species when everyone knows they are only so many "nuts and bolts" is considered unscientific. In order to circumvent this general condition some workers have actually described conodonts with the "collective group" concept in mind and have avoided referring to them as genera or any other collective term. When described collectively under a binominal system of nomenclature, they have considerable utilitarian value. Branson and Mehl (1933), Ellison (1941), and others have found them to be useful in stratigraphic problems. This utilitarian value should not be lost, but at the same time we should recognize the natural genera and species where it is possible to do so. Hass (1941), in an illuminating article on the morphology of conodonts, believes that the present classification should be maintained. He recognizes that "conodont species must be considered as entities that are quite variable in form." I interpret this as meaning that individuals of one collective group belonging to one natural species may differ one from the other. There is not much evidence found in the assemblages to support or refute this premise. Individuals belonging to the same collective group found in different assemblages of the same natural species are remarkably similar, although some may show minute differences that can hardly be considered specific.

An individual conodont has usually been treated as representing a natural genus and species on the assumption that the animal which wore such structures possessed only one kind. Such an assumption is no longer tenable. However, it is recognized that assemblages will seldom be found in lithic zones other than black fissile shales of the Pennsylvanian type. It will be very difficult, if not impossible, to find them in sandstone, limestone, or dolomite.

What constitutes a natural conodont genus? This question will probably never be fully answered, but there is sufficient evidence at hand to show that a natural genus includes an assemblage of teeth. The teeth may consist of several different architectural designs, each type occurring in pairs; in these respects not unlike those found in many animals. The number of pairs present would not be of generic importance. Natural species, according to this viewpoint, would be determined by major differences between any two given pairs of the same collective group from different assemblages.

Individual conodonts have been split into genera on very insignificant details. *Streptognathodus* and *Idiognathodus* are two platelike teeth that are similar in all respects with the exception of a narrow groove down the oral surface of *Streptognathodus*. Ellison (1941) recognizes the variability between individuals of the same species and places many previously described species in the

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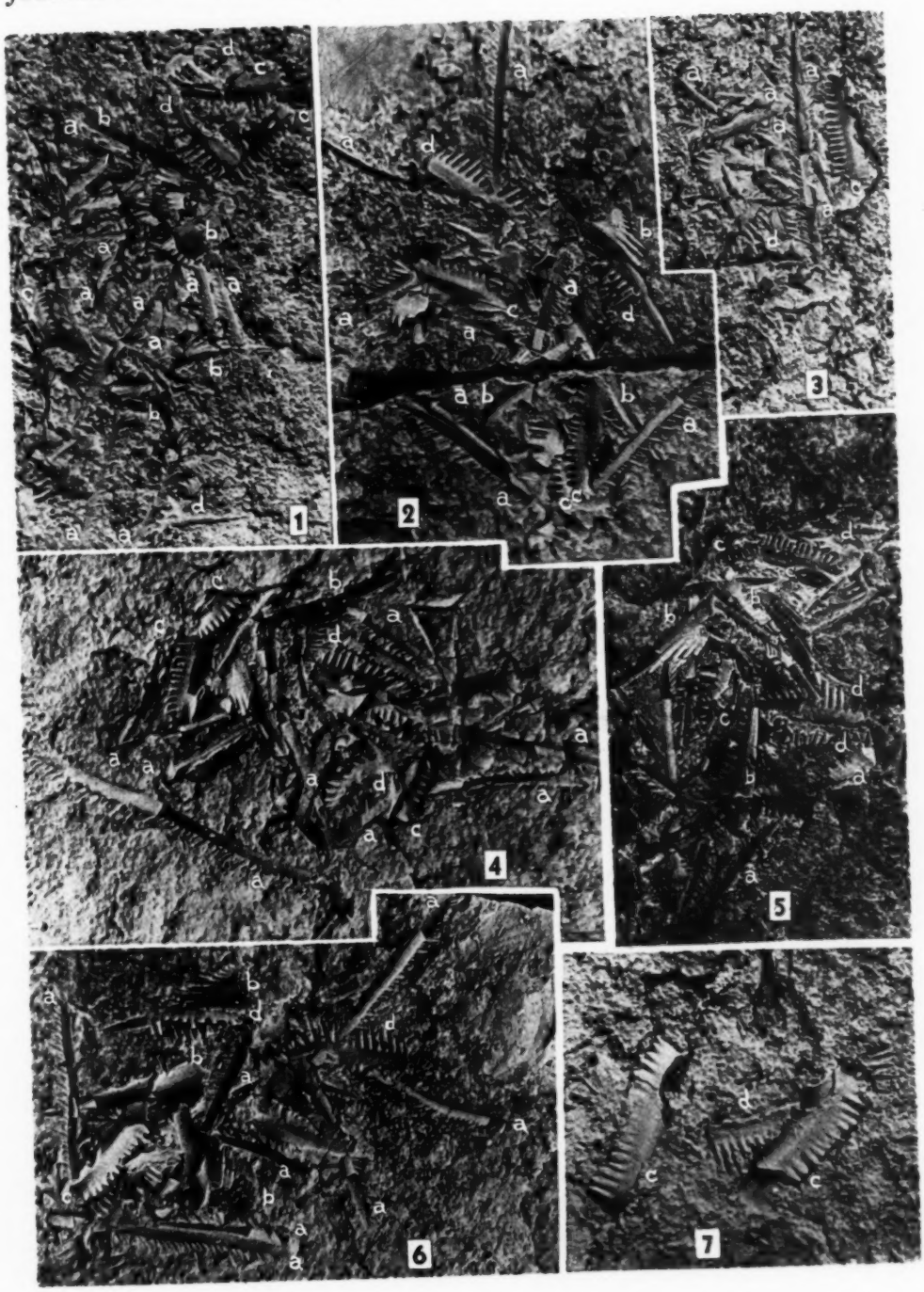
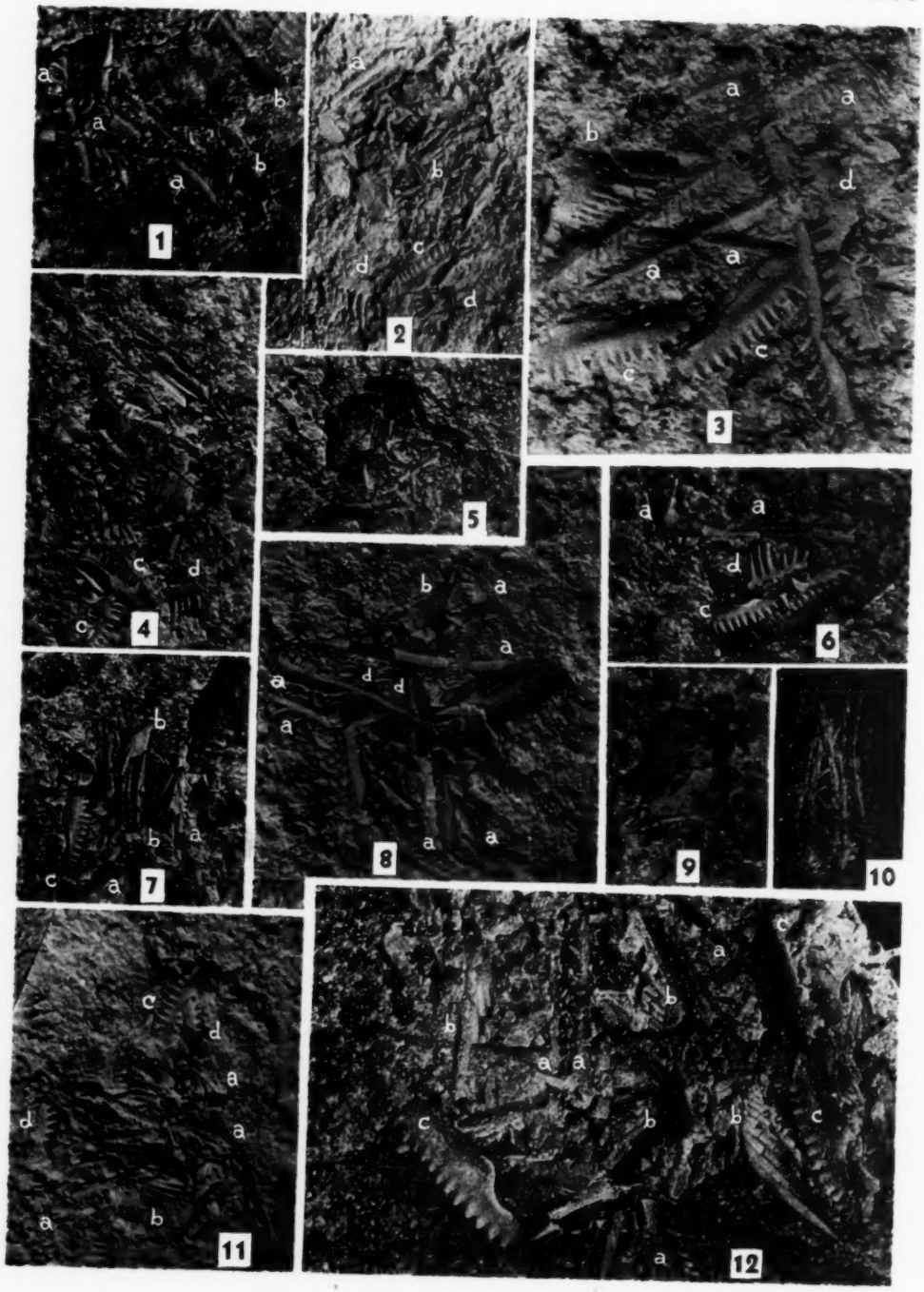
EXPLANATION OF PLATE 37

Untouched photographs; ×25 unless otherwise stated

FIGS. *1–7*—*Lochriea montanaensis* Scott, n. sp. *1*, Individuals within this assemblage are considerably broken; *a*, certainly parts of eight, possibly ten hindeodells; *b*, four prioniods; *c*, four spathognaths; *d*, four prioniodells; notice that a line drawn laterally approximately through midpoint divides the assemblage so that half of each kind of teeth occur above or below the line. *2*, *6*, Positive and negative of the same specimen; *a*, certainly nine, possibly ten hindeodells; *b*, three prioniods; *c*, two spathognaths; *d*, three prioniodells; holotype, Univ. of Illinois no. x-1318. *3*, Incomplete assemblage, approximately one-half; *a*, five hindeodells; *c*, certainly one, possibly two spathognaths; *d*, two prioniodells; prioniods missing. *4*, *5*, Positive and negative of the same specimen; *a*, ten hindeodells; *b*, three prioniods; *c*, four spathognaths; *d*, four prioniodells; certain individuals show up well in one figure but cannot be recognized in the other. The long hindeodell in the lower left of *4* is mostly cut out on the right side of *5*. *7*, Very incomplete assemblage consisting of two spathognaths and one prioniodell, ×30; *c*, two spathognaths; *d*, one prioniodell. (p. 298)



Scott, Conodont Assemblages



Scott, Conodont Assemblages

synonymy. I would go one step further than Ellison by suggesting that such teeth as *Streptognathodus sulcatus* Gunnell (see Ellison, pl. 22, fig. 12, sample 0107, from the Quivira shale) and *Idiognathodus cladiformus* Gunnell (see Ellison, pl. 23, fig. 15, sample 0107, from the Quivira shale) may have come from the mouth of one animal. The similarities between *Bryantodus*, *Subbryantodus*, and *Ozarkodina* are more striking than the differences. It would not be surprising, therefore, to find in one assemblage *Bryantodus* associated with *Hindeodella*, *Prioniodus* and *Spathodus;* whereas, in another assemblage *Subbryantodus* might be present instead of *Bryantodus*.

The Heath assemblages are herein described as natural genera and species. The component parts of the assemblage are designated by common nouns derived from the names of the form genus to which similar parts have heretofore been referred. The names so coined are hindeodell, from *Hindeodella;* spathognath, from *Spathognathodus;* prioniod, from *Prioniodus;* prioniodell, from *Prioniodella;* subbryantod, from *Subbryantodus;* polygnath, from *Polygnathus;* and cavusgnath, from *Cavusgnathodus*. It seems evident that only one kind of animal is represented by the assemblages shown on plate 37, figures 1–7, which include hindeodells, spathognaths, prioniods, and prioniodells. This Carboniferous animal most probably is not congeneric with the genotype on which the oldest form genus was originally based, and to call it by that generic name and to reduce the other names to synonyms, as would be required by the International Rules, not only would be improper but would result in utter confusion.

The generic names of conodonts have often been altered to adjectives, viz., *Idiognathodus* to idiognathodid, or *Hindeodella* to hindeodellid. However, *id* is a suffix derived from *idae* used to form adjectives applying to zoological families and should not be used with generic names.

As conodont assemblages are rare, the established method of describing individual conodonts should be continued, though it should be recognized that the generic names applied to individuals do not represent natural genera. In choosing names for species represented by assemblages, care should be taken to avoid synonyms with any of the component parts.

HEATH ASSEMBLAGES

Approximately 180 conodont assemblages in various stages of perfection have been recovered from the Montana material. The assemblages range from sets of two to sets which apparently approach a complete apparatus as worn by one animal. In addition to the assemblages, approximately 3,000 individuals have been sorted. Most of the different kinds of individual conodonts can be recognized in the assemblages; furthermore the kinds found as individuals are in numbers proportional to those represented in the assemblages, i.e., hindeodells are found approximately three times as often as spatho-

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EXPLANATION OF PLATE 38

Untouched photographs; ×25 unless otherwise stated

FIGS. *1–4, 6, 7, 10, 12—Lochriea montanaensis* Scott, n. sp. *1, a*, Four hindeodells; *b*, two prioniods. *2, a*, Hindeodells, only two fragments visible; *b*, two prioniods; *c*, four spathognaths; *d*, three prioniodells. *3, a*, Four hindeodells, note crossed position similar to fig. 1, pl. 39; *b*, one prioniod; *c*, two spathognaths; *d*, one prioniodell; ×33. *4, a*, Hindeodells, four fragments; *b*, two prioniods, *c*, three spathognaths; *d*, two prioniodells. *6, a*, Two hindeodells; *c*, two spathognaths; *d*, two prioniodells. *7, a*, Five hindeodells, mostly fragments; *b*, two prioniods; *c*, one spathognath. *10, a*, Eight hindeodells, ×14, four oriented with the denticles to the left and four to the right (see Scott, 1934, pl. 58, fig. 2). *12, a*, At least seven hindeodells recognizable; *b*, four prioniods; *c*, four spathognaths; prioniodells missing; ×30. (p. 298)

5—Lochriea? sp.

8—Lochriea bigsnowyensis Scott, n. sp. Holotype, Univ. of Illinois no. x-1320; *a*, at least seven hindeodells; *b*, one prioniod. (p. 299)

9—Brittle, tarlike material often found associated with conodonts. Some of them take the form of the one figured. Notice the minute conodont near lower left corner. (Similar structure in fig. *4*).

11—Lochriea sp. *a*, Five hindeodells; *b*, one prioniod; *c*, one very imperfect spathognath, peculiar shape caused by incomplete imprint; *d*, two prioniodells.

gnaths. Hindeodells, the most common form of conodont in the new genus *Lochriea*, occur in over 50 per cent of the assemblages.

Some conodont faunas show a great variety of individuals. Certain formations have yielded more than 200 nominal species and 25 nominal genera. This seems entirely too many to represent natural genera and species. When the Heath fauna is described from the viewpoint of assemblages, a reasonable number of natural genera and species are present.

If the Heath conodont assemblages represented excreta, as suggested by Branson and Mehl (1936, 1937), there would be numerous broken denticles and a mixture of various kinds of hindeodells as well as other forms. In coprolitic material the shale is usually discolored, and the conodonts lie within the discolored zone in a broken confused mass. The discoloration may take the form of a white, brown, or black splotch. Sometimes coprolites containing conodonts occur as phosphatic or carbonlike spots with teeth more or less buried and broken. The Heath assemblages are not marred by coprolitic discolorations. Furthermore, though some denticles are broken, they do not show the wear and fragmental characteristics of excretal material. Many of the long hindeodells are broken only where the bar overlies some other tooth. Also, it would be strange indeed to find a group of animals that had such a perfectly balanced diet that the excretal material would consist time after time of one pair of prioniods, one pair of spathognaths, one pair of prioniodells, and approximately four pairs of hindeodells. A coprolitic theory for the origin of a great majority of these conodont assemblages is untenable. Less than one per cent of the assemblages in my collection can be attributed to an excretal origin. An examination of the photographs readily shows that the assemblages cannot in any way be related to coprolitic material.

Consideration has been given to the number of individuals actually found as compared with the number that would be expected in a perfect assemblage. There is approximately one assemblage to every 15 individuals; this is on the assumption that an assemblage consists of two or more individuals that show some similar orientation or close relationship. The very incomplete assemblages are more abundant than others. The paired hindeodells (see pl. 39, figs. 1–7) are among the most common. This would seem a natural condition, because these forms were the most common and were more or less adjacent and parallel to each other in life.

Branson and Mehl (1937) explain the occurrence of assemblages "in the light of numerical distribution." Such pairs as those shown in figures 2–6, plate 39, show that these teeth were originally parallel and in contact with each other with markings of one upon the other; that could not be an accidental association. The orientation as shown in such assemblages as figure 10, plate 38, could hardly be explained in the light of numerical distribution, nor could the repetition of similar pairs without a mixture from other natural assemblages be explained on a basis of distribution. Two different assemblages are often found close together, within 2 inches, and yet no mixture of assemblage individuals occurs. It is quite true that such pairs as shown on plate 39, figure 10, might be accidental, but when they are found repeatedly associated and, in addition, are found in more complete assemblages, it seems logical to conclude that most of them are merely incomplete sets.

Assemblages of Pennsylvanian age from Illinois and Kentucky are also in my collection. Similar assemblages have been reported by D. J. Jones (personal communication) from the Pennsylvanian of Oklahoma. All the assemblages thus far reported have been obtained from black fissile shales. They are all generally similar to those herein described. An examination of the literature suggests that certain "assemblage groups" of conodonts may occur in most conodont-bearing horizons.

That the various "collective groups" found in conodont assemblages are not coextensive in their stratigraphic range does not seem to be an unexplainable difficulty. There is no reason to believe that Ordovician conodonts had the same number or kinds of teeth as Pennsylvanian genera. The addition or subtraction of certain kinds of teeth would be a normal consequence of the evolution of the group. The association of spathognaths, hindeodells, prioniods, and

prioniodells in an assemblage does not predicate that all four forms have developed *pari passu* and would have the same stratigraphic range. One special type might have been introduced at a later date, and its appearance would probably represent the development of a new generic kind of animal as well as a new form of tooth.

ASSEMBLAGE CHARACTERISTICS

There are two outstanding features of assemblages; first, the tendency for the teeth to occur in pairs, and second, the lack of a mixture of "assemblage species." For example, at least one pair of spathognaths occurs in plate 37, figures 1, 2, 4–7, also in plate 38, figures 2–4, and 12. At least one pair of similar prioniods occurs in plate 37, figures 2, 4–6, also in plate 38, figures 1, 6, and 12. As nearly as can be determined eight hindeodells occur in plate 37, figures 2, 4–6. Such sets as shown on plate 37, figure 3, with four hindeodells, one spathognath, and one prioniodell, or the one on plate 38, figure 3, with four hindeodells, one prioniod, two spathognaths, and one prioniodell are approximately half assemblages.

Teeth of *Lochriea bigsnowyensis* Scott, n. gen., n. sp. (pl. 38, fig. 8) are not found in any of the assemblages of *L. montanaensis* Scott, n. sp. (pl. 37, figs. 1–7). It seems likely that these two types represent true natural species of the same genus. They are made up of the same general type of teeth, but any given tooth in an assemblage of *L. montanaensis* is specifically different from the corresponding tooth in *L. bigsnowyensis*.

The presence of cavusgnaths and subbryantods with the hindeodells that are characterized by broad blades and strongly cancellated denticles is believed to be an assemblage of conodonts sufficiently different from those in *Lochriea* to warrant the erection of the new genus *Lewistownella*. If conodont assemblages had any origin other than natural groupings of teeth from one animal, then certainly forms from *Lewistownella* would be mixed in with *Lochriea* assemblages. Individuals and assemblages of *Lewistownella* are not common but are easily recognized when found.

The occurrence of conodonts as rights and lefts in the same horizon has been previously recognized by Gunnell (1931), who found dextral and sinistral forms in the Fort Scott limestone of Missouri. Branson and Mehl (1933) recognized such differences and placed such forms in the same species. Right and left forms are adequately represented by *Palmatolyepis subperlobata* Branson and Mehl (1933 pl. 18, figs. 9, 26). It is also of interest to note that approximately half of the forms on this plate are of opposite curvature or orientation than the other half. Similar evidence pertaining to right- and left-hand forms can be found in most of the literature on conodonts. This is well illustrated in a recent paper by Cooper (1939). On his plate 44, 23 species of *Solenognathus* are illustrated. Eleven of these species may be oriented as lefts, 11 as rights, and one as doubtful. On plate 41 of the same report similar differences in orientation may be found, for example, figures 2 and 6, 22 and 29, or 20 and 47. By calling these rights and lefts it is not meant to preclude the possibility of their being uppers and lowers.

THE IDEAL ASSEMBLAGE

The shallow water of the Big Snowy embayment must have been in a partially enclosed area such that the accumulation of black muds took place in exceptionally calm waters undisturbed by wave action. The animals that bore conodonts rested upon this muddy floor at or soon after death. Their body parts decayed, and some of the conodont teeth remained in their approximate natural position where conditions were especially favorable. For the most part gentle currents shifted and separated the teeth so that by far the greater number of them are found as isolated individuals, but a few sets became imbedded in the Heath muds and are preserved as assemblages. Conditions sufficiently favorable for the preservation of conodont assemblages should have permitted the preservation of other hard parts if the conodont-bearing animals had had any.

It is not possible to draw a wholly accurate picture of conodonts as they actually occurred in the living animal. Text figure 1 is purely schematic and is meant to portray the probable arrangement and relative position of conodonts in the genus *Lochriea*. The hindeodells are placed in the center because of such assemblages as shown in plate 38,

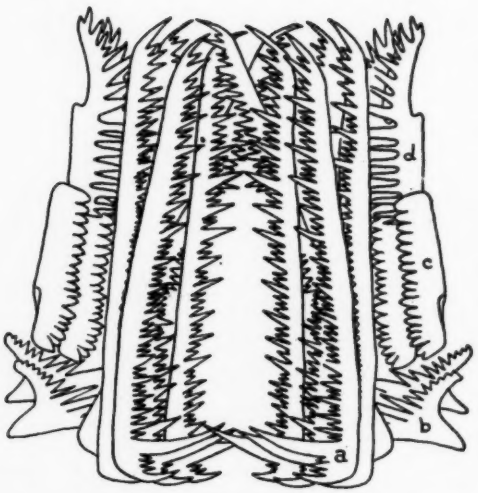


FIG. 1—*Lochriea montanaensis* Scott, n. gen., n. sp. *a*, Hindeodell part; *b*, prioniod part; *c*, spathognath part; *d*, prioniodell part. Position of *b*, *c*, and *d* inferred. Approximately ×30.

figure 10. There is a tendency for the shorter and heavier teeth to be on the outer margin of the assemblages. There is not much question concerning the disposition of the hindeodells, but the position of the prioniods, prioniodells, and spathognaths is a conjectural interpretation, though it is believed that their orientation is approximately correct. They probably operated as rights and lefts, or possibly they were placed in a circular position around an esophageal tract. All of the denticles were set in the soft parts of the animal, as suggested by Scott (1935) and Hass (1941), but could be moved with considerable ease.

The assemblage in figure 1 is not necessarily oriented with the anterior end directed toward the top of the page. The inclination of the denticles has been assumed by all workers to be in a posterior direction, and the point of attachment at the escutcheon was therefore anterior. This is probably true, and with that in mind the prioniods have been oriented with the denticles more or less parallel to the hindeodells, and the escutcheon, in all cases, is directed to the outside of the assemblage. The prioniods, prioniodells, and spathognaths may have been set farther forward or back than shown.

Such an apparatus would not only form an excellent screen to prevent undesirable objects from entering, but would also present a formidable barrier for the escape of desirable food once it had passed beyond the battery of teeth. The manipulation of the assemblage would not be a difficult matter. Insofar as maneuverability is concerned, it could operate with equal ease either as the jaw apparatus of an annelid or as gill rakers of a fish.

SYSTEMATIC DESCRIPTIONS

Genus LOCHRIEA Scott, n. gen.

Natural conodont assemblages made up of hindeodells, spathognaths, prioniods, and prioniodells. One or more of these types may be missing in incomplete assemblages.

Genotype, *Lochriea montanaensis* Scott, n. sp.

LOCHRIEA MONTANAENSIS Scott, n. sp.

Plate 37, figures 1–7; plate 38, figures 1–4, 6–7, 10, 12; plate 39, figures 1, 4, 7, 9; plate 40, figures 2–5, 9–10, 12–13, 15, 18–19; text fig. 1

A perfect assemblage of this species con-

EXPLANATION OF PLATE 39

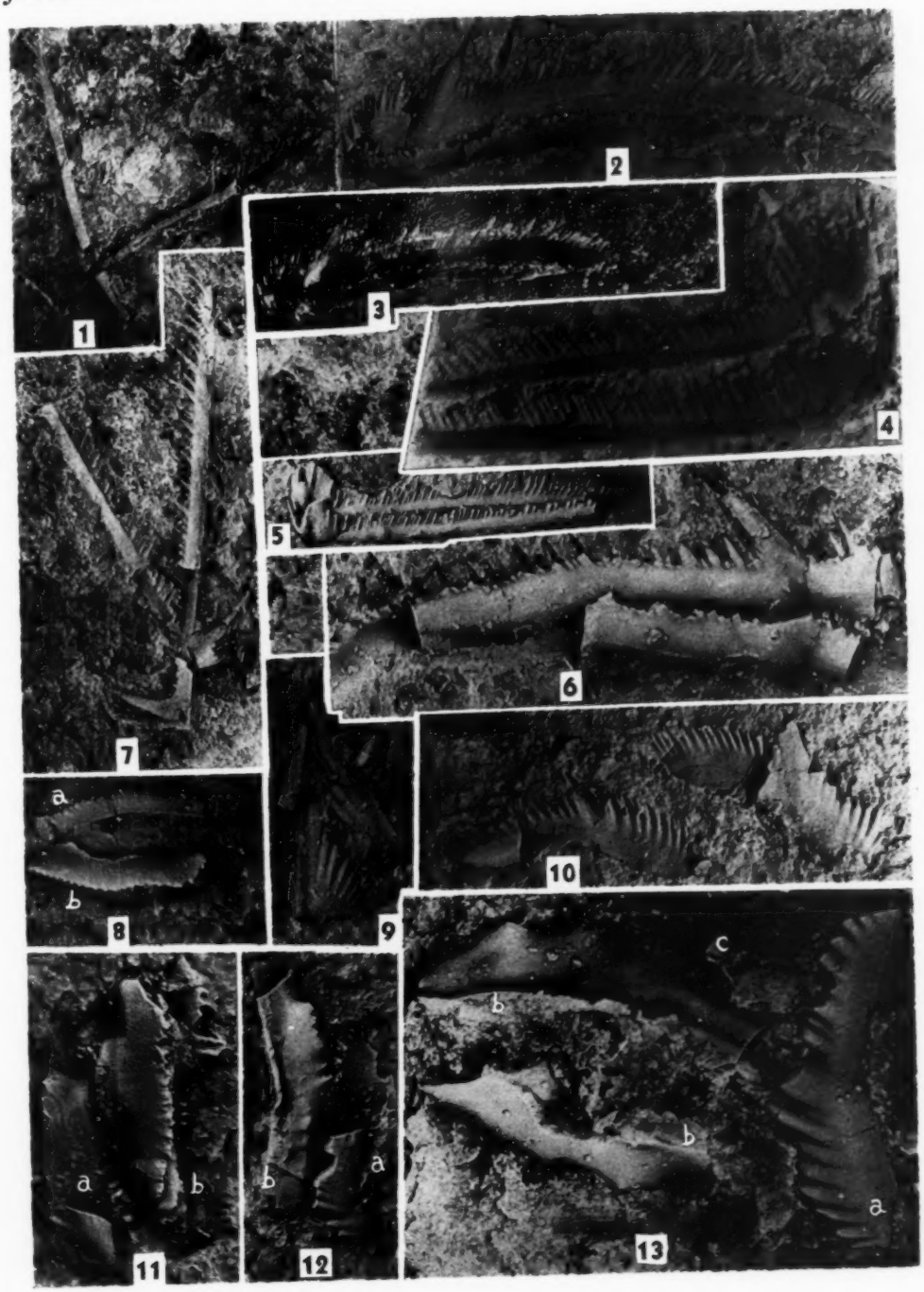
FIGS. *1, 4, 7, 9—Lochriea montanaensis* Scott, n. sp. *1*, Crossing of such paired hindeodells is common. *4*, Imprint of two hindeodells, ×33. *7*, These are right and left specimens as shown by the curvature of the bar anterior to the main cusp. *9*, A pair of prioniods, ×20. (p. 298)

2, 3, 10–13—Lewistownella agnewi Scott. *2*, Ammonium sublimate hides the cancellated structure of the denticles within the bar, ×30. *3*, Same specimen photographed without sublimate coating shows cancellated structure, ×25. *10*, A pair of subbryantods, ×20. *11*, *a*, Broken piece of subbryantod; *b*, cavusgnath; ×25. *12*, *a*, Subbryantod, see *10*; *b*, cavusgnath, ×25. *13*, *a*, Subbryantod, cancellated structure of denticles covered with sublimate; *b*, two partly covered cavusgnaths; *c*, fragment of hindeodell. (p. 300)

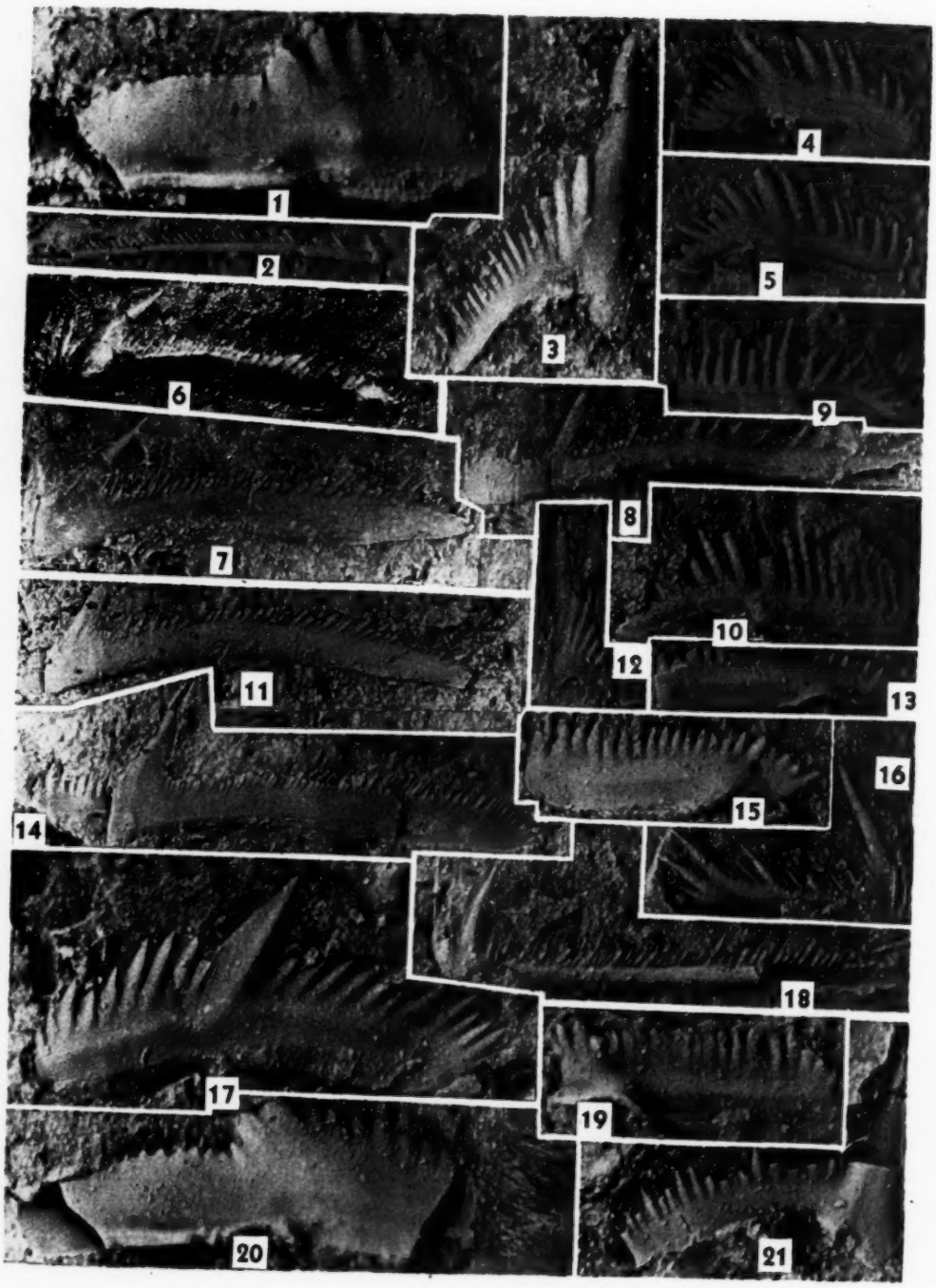
5—This pair belonging to the hindeodell type is the only one found, and the only pair for which a more complete assemblage was not found; ×25.

6—Lochriea? sp. A pair of hindeodells.

8—Lewistownella? sp. ×20. *a*, Hindeodell; *b*, cavusgnath.



Scott, Conodont Assemblages



Scott, Conodont Assemblages

tains at least ten hindeodells, four spathognaths, four prioniods, and four prioniodells.

Hindeodells: Bar narrow, ovate in cross section, long and straight; laterally concavoconvex anterior to cusp; denticles alternating in size, one large to two or three small ones, discrete and inclined; posterior end projected into denticle; cusp large, about three times as large as denticles, preceded by two or three small denticles and one large denticle, which forms anterior termination. Often found in pairs lying adjacent and parallel to each other.

Spathognaths: Blade wide, thin along aboral margin, thickened below base of denticles; denticles short, discrete, subequal in size, tips rounded; escutcheon small, shallow.

Prioniods: Bar wide near cusp, tapering posteriorly to a rounded point; denticles for the most part discrete, about 10 to 12 in number, decreasing in length in direct proportion to the width of the bar, round and tapering most rapidly near the points; cusp large, about twice as long as adjacent denticles; projection long, tapering, sharp-edged; escutcheon moderately deep.

Prioniodells: Bar laterally compressed, widest anterior to escutcheon, thin and tapering posteriorly, slightly arched in posterior half; denticles long, round, subparallel, widely spaced, about 16 in number; escutcheon small, with narrow lateral flange.

Holotype.—Univ. of Illinois no. x–1318
Paratype.—Univ. of Illinois no. x–1319

LOCHRIEA BIGSNOWYENSIS Scott, n. sp.
Plate 38, figure 8; plate 39, figure 6; plate 40, figures 3–5, 8, 14

The most complete assemblage of this species in my collection contains eight hindeodells, two spathognaths, one prioniod, and two prioniodells.

Hindeodells: Bar long, thin in cross section; one, two, or three small denticles set between larger denticles posterior of cusp; cusp long, about three times as long as longest denticle, about 10 denticles anterior of cusp.

Spathognaths: Blade wide, thin along aboral margin; denticles short, tips rounded, escutcheon prominent but shallow.

Prioniods: Bar long, set with approximately 18 denticles; cusp large, projection strong; escutcheon moderately deep.

Prioniodells: Bar bladelike, widest anterior to escutcheon, broadly arched; denticles discrete, about 19 in number, wide at base, tapering to sharp points, smaller thin denticles often occur between larger forms; escutcheon moderately developed.

Holotype.—Univ. of Illinois no. x–1320
Paratype.—Univ. of Illinois no. x–1321

Remarks.—Assemblages and individuals of this species are not common. Hindeodells of this species can be distinguished from those in *L. montanaensis* by the greater length of the bar anterior to the cusp, the larger number of denticles anterior to the cusp, and the greater width of the bar in proportion to its length. The prioniods may be distinguished from those in *L. montanaensis* by the greater length of the bar, the greater number of denticles, and the more circular cross section of the cusp of *bigsnowyensis*. The prioniodells may be distinguished from those in *L. montanaensis* by the wider bar and the generally shorter, wider denticles. Only imprints and fragments of spathognaths have been found in assemblages of *L. bigsnowyensis*. As a result no sharp difference can be pointed out at this time.

Genus LEWISTOWNELLA Scott, n. gen.

Natural conodont assemblages made up

EXPLANATION OF PLATE 40

Untouched photographs; ×35 unless otherwise stated

FIGS. *1, 6, 7, 17, 20, 21*—*Lewistownella agnewi* Scott, n. sp. *1*, Cavusgnath. *6, 7*, Hindeodells; uncoated, showing cancellated denticles, ×27, and coated, ×35. *17*, Subbryantod. *20*, Cavusgnath. *21*, Prioniod, cancellated structure of denticles covered by sublimate. (p. 300)
2, 9, 10, 12, 13, 15, 18, 19—*Lochriea montanaensis* Scott, n. sp. *2*, Hindeodell. *9, 10*, Prioniodells. *12*, Prioniod. *13, 15, 19*, Spathognaths. *18*, Hindeodell. (p. 298)
3–5, 8, 14—*Lochriea bigsnowyensis* Scott, n. sp. *3*, Prioniod. *4, 5*, Prioniodells. *8*, Hindeodell. *14*, Hindeodell, questionably placed in this species. (p. 299)
11—A hindeodell of uncertain assemblage affinities, probably *L. bigsnowyensis* Scott, n. sp.
16—The only specimen of its kind found in the Heath shales.

of hindeodells, prioniods, subbryantods, and cavusgnaths.

Genotype; *Lewistownella agnewi* Scott, n. sp.

Remarks.—The differences between subbryantods and bryantods are so slight that either of these collective groups might reasonably be expected to be associated with the other three types to form the genus *Lewistownella*.

The most complete assemblage of this genus in my collection is the one previously described (Scott, 1934, pl. 58, fig. 5). The specimen labeled *d* in that figure is a cavusgnath. Several attempts to photograph the assemblage have failed to give satisfactory results. The specimen is considered the holotype of *L. agnewi*.

LEWISTOWNELLA AGNEWI Scott, n. sp.
Plate 39, figures 10–13; plate 40, figures 1, 6, 7, 17, 20, 21

Perfect assemblages of this species contain at least four hindeodells, two prioniods, two subbryantods, and two cavusgnaths. The denticles on the hindeodells are cancellate.

Hindeodells: Bar bladelike, set with many slightly irregular, crowded, strongly cancellated denticles; cusp large, five to seven denticles anterior to cusp; aboral margin very broadly concave, rounded at anterior margin.

Prioniods: Bar wide and long, set with about 20 subequal cancellated denticles; cusp long and very thick near base; projection strongly developed.

Subbryantods: Bar wide, long, thin, broadly arched; denticles pointed, subequal in size; cusp large, spatulate, very wide near base, compressed along lateral margins, more compressed than denticles, and two or more times as long as longest denticle.

Cavusgnaths: Plate high in lateral view, aboral margin broadly concave; posterior half of outer oral margin set with two or three large denticles behind several smaller ones; oral surface broad, channel-like, with margins raised; inner oral margin set with many subequal minute nodes or denticles; channel deepest in anterior half of oral area; escutcheon large, deep, elongate, widest at midlength, forming a prominent lateral flare.

Holotype.—Univ. of Illinois no. x–1322

Paratypes.—Univ. of Illinois, no. x–1323

Remarks.—Individuals belonging to *L. agnewi* are not abundant, and only a few assemblages have been found. The most common association is to find a cavusgnath and subbryantod parallel to each other and with the aboral margins either adjacent or opposite.

Locality.—All specimens described and figured came from an outcrop of black fissile shale along the road leading south from Lewistown, Mont., at a point about 6 miles south of the small community of Heath.

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ORDOVICIAN CONODONTS FROM THE BIGHORN MOUNTAINS OF WYOMING

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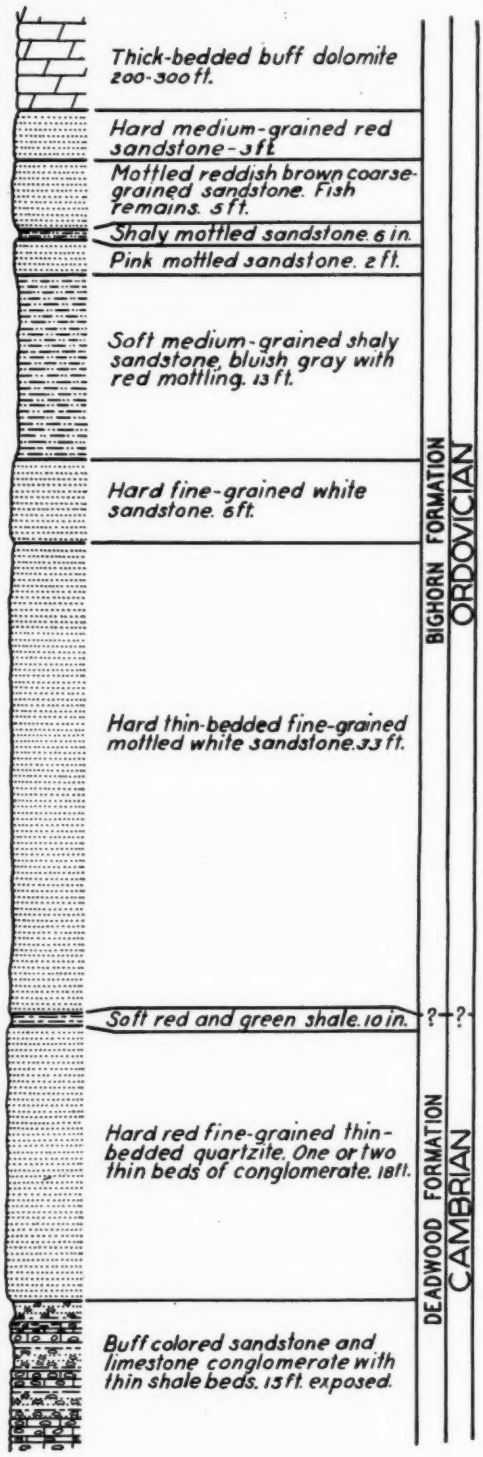
ABSTRACT—Recent collecting in the southern part of the Bighorn Mountains has yielded two Ordovician conodont faunas. The older of these resembles that known from the Harding sandstone of Colorado, whereas the younger is similar to the fauna found in the lower part of the Whitewood formation of the Black Hills. Both of the faunas contain elements that suggest a Middle Ordovician age, but at least the younger may well be referable to the Upper Ordovician.

WITHIN THE past few years Ordovician conodont faunas have been illustrated from Colorado and South Dakota, but only incidental mention has been made of their occurrence in Wyoming. During the summer of 1940 we secured collections from the strata exposed along Crazy Woman and Billy Creeks in the southern portion of the eastern slope of the Bighorn Mountains of Wyoming, and they constitute the basis of the present study. The drawings which accompany our report (pl. 41 and text figs. 1, 2) were prepared by Howard Webster, and acknowledgment is also due to W. M. Furnish for advice and criticism. E. B. Branson and M. G. Mehl kindly agreed to the publication of our report in advance of their own study of conodonts from the area involved.

The Ordovician strata of the Bighorn Mountains and adjacent regions are generally termed the Bighorn formation. However, in 1930 Kirk contended that in much of this area the basal portion of the Ordovician is equivalent in age to the Harding sandstone of Colorado and is distinctly older than typical Bighorn. As is well known, over most of its area of outcrop the Bighorn formation consists of some 200 to 300 feet of hard, impure, buff-colored dolomite, with thin sandy and shaly beds near its base. The lower portions of the dolomite are massive, whereas the uppermost part of the formation is relatively thin-bedded.

For the most part, fossils are not common and are rather poorly preserved in the dolomite, but locally the lower portions of the formation are abundantly fossiliferous. In 1904, when Darton originally described the Bighorn formation, he concluded that it is Late Ordovician in age. However, in 1906 he stated that Ulrich had studied his fossils and that the massive dolomite member should be correlated with the Black River and lower Trenton, whereas the upper thin-bedded portion of the formation is Richmond in age. Within the past decade Miller and Foerste have referred the Bighorn to the Upper Ordovician, but Kay is apparently of the opinion that it should be placed in the Middle Ordovician. At the same time Kirk maintains that there are both Middle and Upper Ordovician sandstone members in the lower part of the beds generally referred to the Bighorn; he concludes that the upper of these sandstones is "lower Cincinnatian" whereas the lower is "probably about late Black River or early Trenton" in age and is the equivalent of the Harding sandstone of Colorado. Ulrich, however, has recently restudied the fauna of the Harding and stated that it is "probably early Richmond." In 1936 Furnish, Barragy, and Miller identified a considerable conodont fauna from the lower clastic portion of the Whitewood formation in the Black Hills, which is the equivalent of the Bighorn, and they concluded that it is referable to the "Middle? Ordovician." They were, however, careful to point out that the "typical Whitewood dolomite presumably is Upper Ordovician in age."

It now seems clear that, on the basis of its fauna, the Bighorn formation can be readily correlated with beds outcropping to the north in Canada and Greenland and to the south in both United States and Mexico. However, correlations to the east are much more difficult, and it is still not certain whether the fauna of the main portion of the Bighorn dolomite is closer to that of the Stewartville formation (upper Galena) or to that of the slightly younger Maquoketa


Thick-bedded buff dolomite 200-300 ft.
Hard medium-grained red sandstone-3 ft
Mottled reddish brown coarse-grained sandstone. Fish remains. 5 ft.
Shaly mottled sandstone. 6 in.
Pink mottled sandstone. 2 ft.
Soft medium-grained shaly sandstone, bluish gray with red mottling. 13 ft.
Hard fine-grained white sandstone. 6 ft.
Hard thin-bedded fine-grained mottled white sandstone. 33 ft.
Soft red and green shale. 10 in.
Hard red fine-grained thin-bedded quartzite. One or two thin beds of conglomerate. 18 ft.
Buff colored sandstone and limestone conglomerate with thin shale beds. 15 ft. exposed.
BIGHORN FORMATION
ORDOVICIAN
DEADWOOD FORMATION
CAMBRIAN
? ?

shale of the upper Mississippi Valley. Furthermore, there is no unanimity of opinion as to the age of the Stewartville, and it may well be referable to the Upper Ordovician, as is the Maquoketa.

The conodonts obtained by us came from the canyons of Billy and Crazy Woman Creeks, the same general area in which Branson and Branson (1941, p. 129) recently recorded their occurrence. In 1930 Kirk reported on the Ordovician section exposed along Billy Creek, in the southern portion of the Fort McKinney quadrangle, about 15 miles south of Buffalo. This section consists of about 45½ feet of sandstone capped by some 250 feet of massive dolomite. The base of the sandstone is covered by talus. The lowest beds visible outcrop as a steep cliff about 20 feet high. They are thin-bedded fine-grained white sandstone, which locally is quartzitic. Above this cliff is about 5 feet of white medium-grained fairly resistant sandstone and 10 feet of shaly sandstone, which forms a relatively gradual slope. These are overlain by 2 feet of hard mottled sandstone, 6 inches of bluish-gray shaly sandstone somewhat mottled with red, and 5 feet of fairly coarse red sandstone, which carries an abundance of fragmentary fish remains. Then comes the uppermost bed of the clastic portion of the Bighorn formation, which here consists of 3 feet of rather soft and friable medium-grained iron-stained sandstone. This sandstone seems to be separated from the underlying beds by a slight disconformity or diastem. It contains a few rather poorly preserved representatives of *Receptaculites* and *Endoceras* and rare gastropods, in addition to conodonts, which occur also in all of the underlying members just discussed. The majority of the conodonts obtained at this locality came from the 10 feet of sandy shale, and most of the remainder came from the lower 20-foot sandstone cliff, only a few forms being found in the uppermost sandstone.

Five miles north of Billy Creek, on Crazy Woman Creek, an excellent section of the lower portion of the Bighorn formation (see text fig. 1) is now exposed along a new road that has recently been cut in the canyon

FIG. 1—Section of lower portion of Bighorn formation exposed in canyon of Crazy Woman Creek in southern Bighorn Mountains.

TABLE 1. KNOWN DISTRIBUTION OF ORDOVICIAN CONODONTS IN LOWER CLASTIC MEMBERS OF BIGHORN FORMATION IN SOUTHERN BIGHORN MOUNTAINS

Conodont genera and species	Bighorn sandstone of Wyoming	Whitewood shale and siltstone of South Dakota	Harding sandstone of Colorado	Platteville formation of Minnesota	Decorah formation of Minnesota	Plattin limestone of Missouri	Joachim dolomite of Missouri
ACONTIODUS Pander	×	×		×			
A. sp.	×						
BELODUS Pander	×	×		×	×	×	?
B. sp.	×						
OISTODUS Pander	×	×		×	×	×	
O. curvatus Branson and Mehl	×	×		×	×	×	
PALTODUS Pander	×	×		×	×	×	
P. sp.	×						
PTEROCONUS Branson and Mehl	?	×		×	×	×	×
P.? sp.	×						
BRYANTODINA Stauffer	×	×		×			
B. sp.	×						
CHIROGNATHUS Branson and Mehl	×	×	×	×		×	
C. alternata Branson and Mehl	×		×	×			
C. curvidens Branson and Mehl	×		×				
C. delicatulus Stauffer	×	×		×			
C. monodactyla Branson and Mehl	×		×				
C. multidens Branson and Mehl	×		×	×			
C. reversa Branson and Mehl?	×		×				
C. tenuidentatus Branson and Mehl	×			×			
C. unguliformis Stauffer?	×			×			
COLEODUS Branson and Mehl	×		×				×
C. simplex Branson and Mehl	×		×				
CORDYLODUS Pander	×	×	×	×		×	
C.? concinnus Branson and Mehl	×					×	
CYRTONIODUS Stauffer	×	×		×			
C. complicatus Stauffer	×			×			
C. erectus Stauffer	×	×		×			
DREPANODOS Pander	×						
D. sp.	×						
ERISMODUS Branson and Mehl	×	×	×	×		×	
E. abbreviatus Branson and Mehl?	×		×				
E. typus Branson and Mehl	×		×				
LONCHODUS Pander	×			×			
L. sp.	×						
MICROCOELODUS Branson and Mehl	×	×		×			×
M. breviconus Branson and Mehl	×						×
M. unicornis Branson and Mehl?	×						×
NEOCOLEODUS Branson and Mehl	×		×				
N. spicatus Branson and Mehl?	×		×				
POLYCAULODUS Branson and Mehl	×					×	×
P. bidentatus Branson and Mehl?	×					×	
PTEROCONUS Branson and Mehl	×	×		×		×	×
P. gracilis Branson and Mehl	×					×	
STEROCONUS Branson and Mehl	×		×	×			×
S. gracilis Branson and Mehl	×		×	×			
S. plenus Branson and Mehl?	×		×				×
S. robustus Branson and Mehl	×		×				

wall. Fresh exposures of all of the beds between the top of the Deadwood (Cambrian) and the typical Bighorn dolomite are readily available. There appears to be no marked physical unconformity in the clastic beds that outcrop here, and therefore uncertainty exists as to where the boundary between the Cambrian and the Ordovician

should be drawn. All of the beds from which significant fossils were obtained are being placed in the Ordovician and regarded as part of the Bighorn formation. The Deadwood-Bighorn (Cambrian-Ordovician) boundary as thus defined comes on top of a 10-inch bed of soft red and green shale that carries cystoid columnals and below 33 feet of hard thin-bedded fine-grained white sandstone with poorly preserved brachiopods and gastropods. The 10-inch shale member is about 18 feet above the limestone conglomerate that is so characteristic of the upper portion of the Cambrian in the Northwest. This 18-foot interval is occupied by a thin-bedded unfossiliferous red quartzite.

Above the 33 feet of thin-bedded white sandstone on Crazy Woman Creek is a 6-foot layer of hard fine-grained white sandstone that is overlain by about 13 feet of soft medium-grained shaly bluish-gray sandstone with some red mottling. This in turn is overlain by 2 feet of medium-grained white and red mottled sandstone, 6 inches of mottled shaly sandstone, and 5 feet of reddish-brown coarse-grained sandstone, which carries an abundance of fish fragments. The uppermost clastic bed at this locality consists of 3 feet of dense iron-stained medium-grained sandstone with poorly preserved representatives of *Receptaculites* and *Endoceras*. This last-men-

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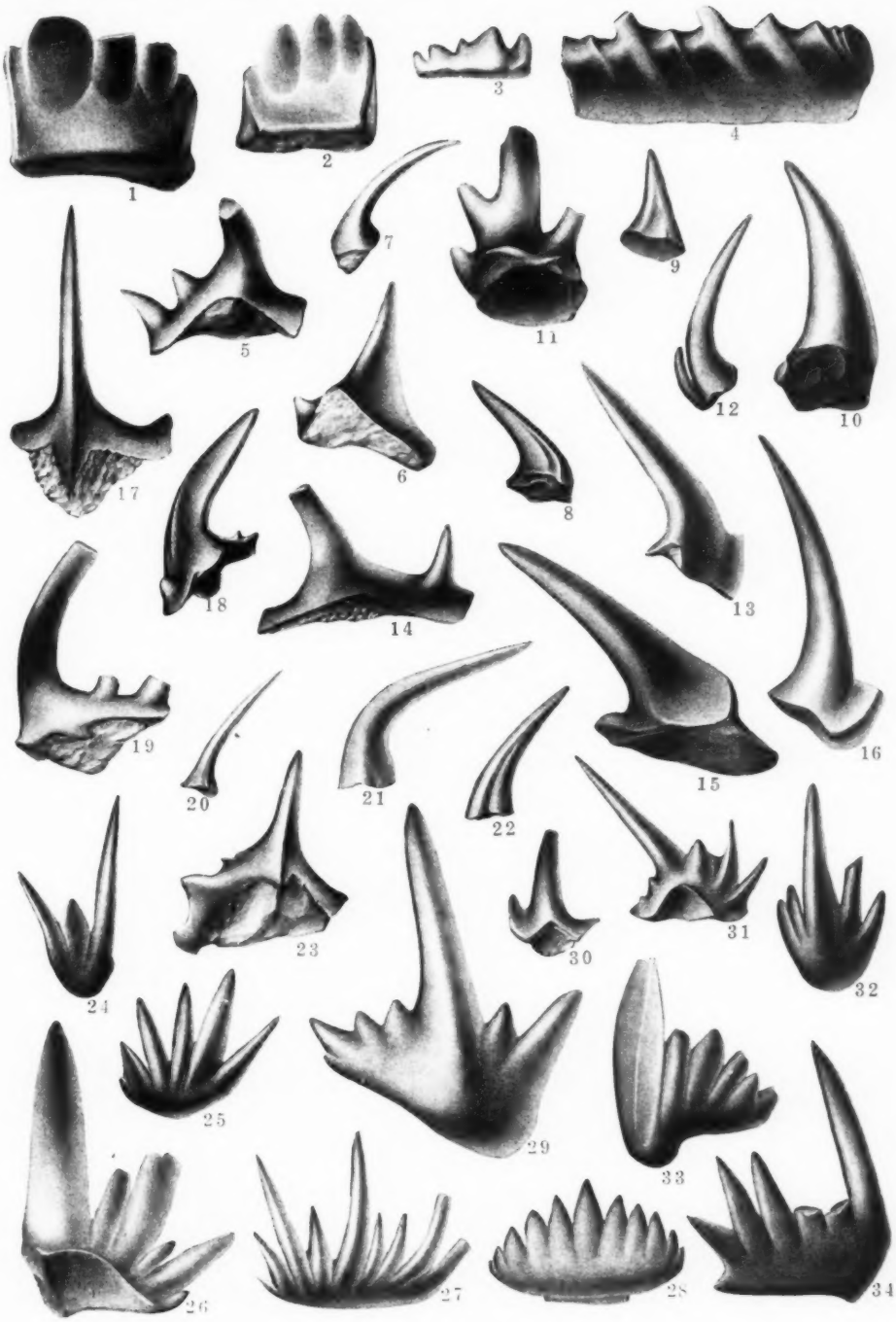
EXPLANATION OF PLATE 41

All specimens came from the lower portions of the basal clastic part of the Bighorn formation on Billy and Crazy Woman Creeks in the southern Bighorn Mountains. They are State University of Iowa nos. 1623–1656, inclusive.

FIG. *1*—*Coleodus* sp., ×55; from base of 33-foot sandstone on Crazy Woman Creek.
2—*Coleodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
3—*Neocoleodus* sp., ×25; from base of 33-foot sandstone on Crazy Woman Creek.
4—*Lonchodus?* sp., ×70; from 5-foot sandstone on Billy Creek.
5—*Microcoelodus unicornis* Branson and Mehl?, ×70; from 10-foot sandy shale on Billy Creek.
6—*Microcoelodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
7—*Stereoconus* sp., ×25; from base of 33-foot sandstone on Crazy Woman Creek.
8—*Stereoconus robustus* Branson and Mehl, ×25; from midportion of 33-foot sandstone on Crazy Woman Creek.
9—*Stereoconus plenus* Branson and Mehl?, ×25; from base of 33-foot sandstone on Crazy Woman Creek.
10—*Stereoconus* sp., ×70; from base of 33-foot sandstone on Crazy Woman Creek.
11—*Polycaulodus* sp., ×55; from midportion of 33-foot sandstone on Crazy Woman Creek.
12—*Polycaulodus* sp., ×55; from 10-foot sandy shale on Billy Creek.
13—*Polycaulodus* sp., ×70; from base of 33-foot sandstone on Crazy Woman Creek.
14—*Microcoelodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
15—*Polycaulodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
16—*Polycaulodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
17—*Erismodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
18—*Pteroconus gracilis* Branson and Mehl, ×25; from base of 33-foot sandstone on Crazy Woman Creek.
19—*Cordylodus? concinnus* Branson and Mehl, ×70; from 10-foot sandy shale on Billy Creek.
20—*Drepanodus?* sp., ×25; from 5-foot sandstone on Billy Creek.
21—*Drepanodus?* sp., ×25; from 5-foot sandstone on Billy Creek.
22—*Stereoconus gracilis* Branson and Mehl?, ×25; from base of 33-foot sandstone on Crazy Woman Creek.
23—*Microcoelodus* sp., ×70; from 10-foot sandy shale on Billy Creek.
24—*Chirognathus tenuidentatus* Stauffer?, ×70; from 10-foot sandy shale on Billy Creek.
25—*Chirognathus unguliformis* Stauffer?, ×55; from 10-foot sandy shale on Billy Creek.
26—*Chirognathus alternata* Branson and Mehl, ×70; from 10-foot sandy shale on Billy Creek.
27—*Chirognathus delicatulus* Branson and Mehl, ×70; from 10-foot sandy shale on Billy Creek.
28—*Chirognathus multidens* Branson and Mehl, ×55; from 10-foot sandy shale on Billy Creek.
29—*Chirognathus* sp., ×70; from 2-foot sandstone on Billy Creek.
30—*Chirognathus curvidens* Branson and Mehl?, ×70; from base of 33-foot sandstone on Crazy Woman Creek.
31—*Chirognathus monodactyla* Branson and Mehl, ×70; from 10-foot sandy shale on Billy Creek.
32—*Chirognathus* sp., ×55; from base of 33-foot sandstone on Crazy Woman Creek.
33—*Cyrtoniodus erectus* Stauffer, ×70; from 10-foot sandy shale on Billy Creek.
34—*Cyrtoniodus complicatus* Stauffer, ×70; from 10-foot sandy shale on Billy Creek.



Amsden and Miller, Ordovician Conodonts

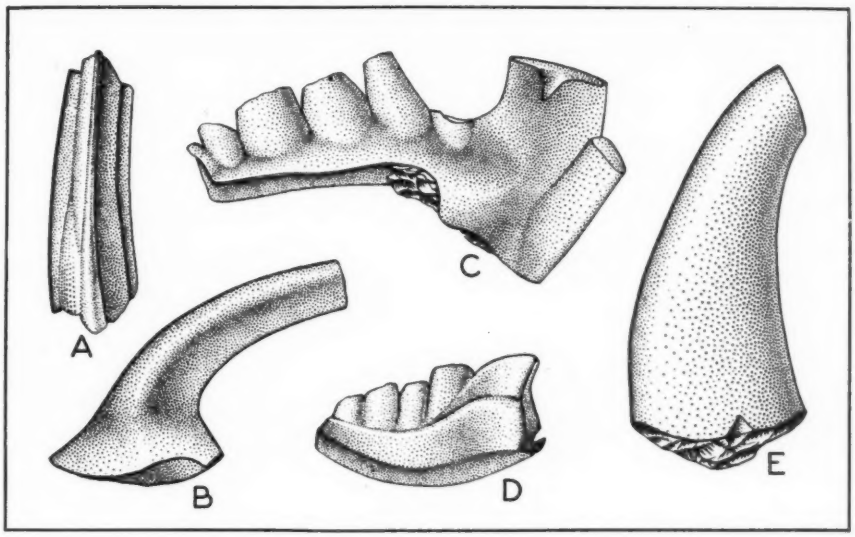


FIG. 2—Conodonts from the 3-foot sandstone bed that immediately underlies the dolomitic portions of the Bighorn formation on Billy Creek in the southern part of the Bighorn Mountains. A, *Acontiodus* sp.; B, *Oistodus curvatus;* C, *Pteroconus?* sp.; D, *Belodus* sp.; and E, *Paltodus* sp.—all ×70. The specimens on which these drawings are based are at the State University of Iowa, where they are numbered 1618–1622, inclusive.

tioned bed is overlain by the massive dolomite portion of the Bighorn formation, and it appears to be separated from underlying strata by a slight unconformity or diastem. Most of the conodonts obtained from this Crazy Woman Creek section came from the basal 33-foot sandstone, but a few specimens were obtained from all of the overlying Ordovician clastic units except the uppermost 3-foot one. It should perhaps be emphasized that this section corresponds very closely to that exposed on Billy Creek, and it indicates that at the latter locality only the basal portion of the Ordovician beds are covered.

As shown by table 1, altogether representatives of seventeen genera of conodonts were obtained from the lower clastic portions of the Bighorn formation along Billy and Crazy Woman Creeks, there seems to be no great difference between the faunas at these two localities, and, with the exception of the uppermost sandstone bed, there does not appear to be any significant difference in the conodonts of the various units into which the clastic portion of the formation is being divided. The uppermost sandstone has yielded representatives of only five genera of conodonts, but, with the possible exception of *Pteroconus*, none of them is represented in the underlying beds.

Recently Branson and Mehl described a fairly large conodont fauna from the Harding sandstone of Colorado, and many of the species represented in the collection under consideration occur also in the Harding (see table 1). At least six genera of conodonts are common to the Harding and lower Bighorn. Furthermore, the extensive conodont fauna known from the Platteville formation of Minnesota is very similar to that of the lower Bighorn and contains many genera in common with it. Similarities are also apparent with the conodonts of the Plattin of Missouri and to a lesser extent with those of the Joachim of Missouri. The Joachim, Plattin, and Platteville are now almost universally regarded as Middle Ordovician, and the Harding is believed by most stratigraphers to belong in the same series, though Ulrich has recently stated that it is "much younger—probably early Richmond."

The uppermost bed of the clastic portion of the Bighorn formation, a 3-foot sandstone, is fairly hard on Crazy Woman Creek, and it would be difficult to obtain micro-

fossils from the outcrops there. However, on Billy Creek the same sandstone is somewhat softer, and it yielded representatives of five condont genera: *Acontiodus*, *Belodus*, *Pteroconus?*, *Oistodus*, and *Paltodus* (text fig. 2). This assemblage, though small, is probably very significant for, with the possible exception of *Pteroconus*, not one of the genera of which it is composed is represented in the underlying beds of the Bighorn formation, but all of them occur in the lower portion of the Whitewood formation of the Black Hills —the specimen that we are referring with question to *Pteroconus* is very similar to a Whitewood form. These facts seem to us to support strongly Kirk's contention that there are two distinct horizons represented in the clastic beds which constitute the lower portion of the Bighorn formation in the southern Bighorn Mountains, though both of the conodont faunas display a perplexing analogy with that of the Platteville. Furnish, Barragy, and Miller have recently discussed at some length the age of the conodont fauna of the lower Whitewood and concluded that it is "Middle? Ordovician." We are not able to add to their discussion from our small representation of what appears to be the same fauna. However, it should be born in mind that conodonts have been studied intensively for only a rather short time, and that therefore the range of most of the genera and species is not yet known. Furthermore, no abundant and diversified conodont faunas have been described from undoubted Upper Ordovician strata, and until the nature of the conodonts of that series is known, it will not be possible to reach a definite conclusion in regard to the age of the forms that occur in the Bighorn and associated formations.

SUMMARY

The lower clastic portions of the Bighorn formation in the canyons of Billy and Crazy Woman Creeks on the eastern slope of the southern Bighorn Mountains contain numerous conodonts. The fossils in all but the uppermost of these clastic beds indicate a close relationship to the fauna of the Harding sandstone of Colorado and to that of the Platteville limestone of Minnesota, and they are somewhat similar to those of the Plattin and Joachim formations of Missouri. The fauna of the uppermost clastic bed in the Ordovician of the Bighorns, a 3-foot sandstone, is unlike that of the beds below it but is very similar to that known from the basal shale and siltstone of the Whitewood formation in the Black Hills. Both of these conodont faunas seem to indicate a Middle Ordovician age for the containing beds, but at least the younger one may well be referable to the Upper Ordovician.

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MIOCENE MOLLUSCS FROM COSTA RICA

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ABSTRACT—36 forms were recognized in a collection of about 185 specimens sent to the Field Museum of Natural History from the Museo Nacional of Costa Rica. The material, consisting of 26 forms of pelecypods (2 new), 1 scaphopod, and 9 forms of gastropods of which 3 were not previously described, was obtained from Carballo on the Pacific Coast, from various localities in the Central Highlands, and from unknown localities; the matrix and association of some fossils from these localities strongly suggest the probability of their belonging to the Carballo fauna.

The Carballo assemblage is the largest in the collection. It has a close affinity with the Gatun fauna and is believed to be of middle Miocene age. No exact stratigraphic correlation within the Miocene of the forms from the various other localities is ventured.

The majority of the species not restricted to the Gatun fauna are Carribean types; there are, however, two species hitherto known only from the Californian Miocene and two from the middle Miocene Chesapeake group.

IN SEPTEMBER, 1940, the writer was entrusted with a collection which had been sent for identification to the Field Museum of Natural History, Chicago, through the courtesy of Don Juvenal Valerio, Director of the Museo Nacional of San José, Costa Rica. In addition to the molluscs here dealt with, the collection includes a single brachiopod, the matrix of which does not agree with that of any of the other specimens and which can be identified solely as *Rhynchonella* (s. l.) sp. Its age seems to be Mesozoic, may be Jurassic. There are, furthermore, some corals, a part of them obviously recent, which will be reported on elsewhere.

The writer is deeply indebted to Dr. H. W. Nichols, Chief Curator of Geology,[1] for having kindly supplied the petrographical data mentioned below and, moreover, for having furthered the writer's work in every way and given him every facility available; to Dr. Fritz Haas, Curator of Lower Invertebrates,[1] for kind permission to study Field Museum's collections of recent molluscs for comparison and for having placed most generously his immense knowledge of recent forms at the writer's disposal; to Mr. Bryan Patterson, Assistant Curator of Paleontology,[1] for most valuable suggestions aiding the study; to Mr. Paul O. McGrew, Assistant Curator of Paleontology;[1] Mr. B. Mather, Assistant Curator of Mineralogy,[1] and Mrs. B. Mather for kind assistance in assembling the literature; to Mrs. Mather, moreover, for a most valuable hint about the geological age of the Shoal River formation of Florida, and to Mr. Cecil Underwood of San José, Costa Rica, for having most obligingly secured some information on the site of the locality "Carballo." Finally, the writer wishes to express his gratitude to Dr. H. E. Vokes, Assistant Curator of Invertebrate Palaeontology, The American Museum of Natural History, for his most kind assistance in the preparation of the present paper and the accompanying photographs.

[1] Field Museum of Natural History, Chicago.

HISTORICAL SUMMARY

The presence of Tertiary deposits, "later than the Eocene," seems to have been first noted by Gabb (1874a, p. 438) who had explored Costa Rica, especially its southeastern part, in 1873 and 1874. In a second note of the same year (1874b, p. 389) are first mentioned Miocene rocks, which are more explicitly discussed in a paper of 1875 (pp. 201, 203–204). A fourth report of Gabb's on his exploration in Costa Rica appeared, in Spanish, 20 years later (1895). Its first part was reprinted without reference to its original source in 1911.

Although some species of the Miocene fauna of the Gatun stage, found primarily near Gatun, Panama Canal Zone, had been described by Conrad as early as 1856, that fauna was first thoroughly studied by Toula (1909) and, only a few years later, by Brown and Pilsbry (1911-1912).

Meanwhile the geology of those parts of Costa Rica which have furnished the material dealt with in the present paper had been discussed by Hill (1898) in his paper on "The geological history of the Isthmus of Panama and portions of Costa Rica," part 3 describing the Pacific coast from Panama to Punta Arenas, and part 4, "A continental section across Costa Rica in the longitude of San José, from Punta Arenas to Port Limon." In 1912, Romanes published a paper on the "Geology of a part of Costa Rica," recording the localities Carballo, Patarrá and Agua Caliente and listing seven species of Tertiary molluscs from the Miocene deposits at the mouth of the Barranca River, a few miles northwest from Carballo, among them "*Mactrinula*" *macescens* Guppy, *Clementia dariena* Conrad, and *Turritella* cf. *gatunensis* Conrad; references to previous literature on the geology of Costa Rica are found in Romanes' paper, but an essay "Comprobaciones geológicas" by Anastasio Alfaro, published just a year before in San José, had escaped him. In Alfaro's essay the fossiliferous localities in and near the tunnel of Carballo are graphically described (pp. 124-126), and those of Patarrá and Tablazo are mentioned (pp. 128–129). Along with other fossils from there, some Pectens are recorded (cf. Woodring, 1928, p. 89).

In 1922, Olsson published his important paper on the Miocene of Costa Rica, dealing chiefly with the molluscs of the Gatun stage. Reference has, of course, been made to his work in almost all the later papers on Tertiary molluscs of the Americas but, as far as the writer knows, no publication dealing explicitly with those of Costa Rica has appeared since.

Woodring's (1926) monograph of the genus *Clementia* refers one broken specimen ("identification doubtful") from "Carballo Cliff, East of Punta Arena" and another example from "Caldera, near Corballo tunnel" to *Clementia dariena dariena*, considering both of them as of lower Miocene age. In Part II of his work on "Miocene Mollusks from Bowden Jamaica" (1928, p. 88) this author states that no Miocene fossils have ever been recorded from the Pacific coast of Costa Rica, but those two specimens and those mentioned by Romanes in 1912. In his later paper Woodring mentions also some poorly preserved material from Carballo Cliff and Carballo tunnel in the collections of the U. S. National Museum, which he states to be "undoubtedly Miocene," adding that "it seems to be of the same age as the lower Miocene beds of Panama." The limestones of Patarrá and other localities of the Central Highland are believed by him to be still older, though certainly not Cretaceous, as supposed by Hill (1898).

FAUNAL LIST

The results of the examination of the molluscs are shown in the following list, in which the number preceding the locality indicates the number of specimens, and that following it is the catalogue number of the Museo Nacional at San José.

PELECYPODA

1. *Arca* (*Noetia*) *macdonaldi* Dall var. *subreversa* Olsson, 1, locality?, 776. Considered to be the typical *Arca* (*Noetia*) *macdonaldi* Dall by MacNeil (1938, pp. 35, 36, pl. 6, figs. 10–13).
2. *Cardium* (*Fragum*) *medium* Linné, 1, locality?, ex 776; 1, Carballo, ex 825.

2a. *Cardium* (*Fragum*) *medium* Linné?, 1, locality?, 771.

3. *Cardium* (*Cerastoderma*) *waltonianum* Dall, 1, Carballo, 765. Described (1890–1903, pt. 5, p. 1093, pl. 48, fig. 19) from some beds of Walton County, Florida, which were referred to the Oligocene (?), but since proved by Gardner (1926–1937, pt. 3, p. 102, pp. 139–140, pl. 23, fig. 8) to belong to the Shoal River formation, the uppermost part of the (middle Miocene) Alum Bluff group.
4. *Cardium* (*Trachycardium?*) *tamanense* Maury, 1, Carballo, ex 765. Described (1925, p. 129, pl. 22, fig. 6) from the Tamana Miocene of Trinidad.
5. *Antigona* (*Circumomphalus*) *harrisiana* Olsson, 1, locality?, 814.
6. *Clementia dariena* (Conrad), 1, Carballo, 778.
7. *Clementia inoceriformis* (Wagner), 2, Carballo, 815, 816; Punta Carballo, 819. Hitherto known only from the middle Miocene Chesapeake group of Maryland and New Jersey (see Palmer, 1927,

p. 203, cum synon., pl. 25, figs. 10, 13, pl. 26, fig. 13a).

8. *Chione* (*Chione*) *costaricensis* Olsson?, 1, locality?, ex 780.
9. *Chione* (*Chione*) *walli* (Guppy), 8, Carballo, 781, ex 769, ex 825; 1, locality?, ex 771. Hitherto known only from the Manzanilla Miocene of Trinidad (see Palmer, 1927, p. 147, cum synon., pl. 39, figs. 13, 14, 16, 19).
10. *Chione* (*Lirophora*) *mactropsis* (Conrad), 2, Carballo, 769. The "posteriorly lengthened" type of *Chione* (*Lirophora*) *ulocyma* Dall with the "narrow attenuated shape," as figured by Palmer, 1927, pl. 45, fig. 5, agrees in shape far better with *Ch.* (*L.*) *mactropsis* than with *ulocyma*, although its ornament is that of *Ch. ulocyma*. This type is obviously transitional between both species. (In Palmer, 1927, p. 176, 6th line of 3d paragraph, the name "*mactropsis*" has obviously to be replaced by the name "*ulocyma*.")
11. *Chione* (*Lirophora*) *alveata* (Conrad), 1, Carballo, 832. Hitherto known only from the middle Miocene Chesapeake group of Maryland and Virginia (see Palmer, 1927, p. 171, cum synon., pl. 41, figs. 5, 8, 9, 20, 24, 36, 40).
12. *Chione* (*Anomalocardia*) *brasiliana* (Gmelin), 1, Carballo, ex 765. Hitherto known from the upper Miocene and Pliocene of Trinidad, the Pliocene and Pleistocene of Brazil, and Recent of North Carolina, the West Indies and Brazil (see Palmer, 1927, p. 167, cum synon., pl. 36, figs. 5–8, 15–18).
13. *Gafrarium* (*Gouldia*) *erosum* Dall, 1, Carballo, 827. Larger than Dall's holotype (length 12 mm. as compared to 8.3 mm. in the latter). This species hitherto known only from the lower Micoene of Florida (see Dall, 1890–1903, pt. 6, p. 1248, pl. 57, fig. 10; Palmer, 1927, p. 100, pl. 21, fig. 10).
14. *Sanguinolaria* (*Sammotella*) *alouatta* Olsson?, 1, Carballo, 826.
15. *Semele laevis* Sowerby, var. *costaricensis* Olsson, 1, locality?, 779.
16. *Semele?* sp. indet., 2, locality?, ex 770 and ex 779.
17. *Labiosa* (*Labiosa*) cf. *alata* (Spengler) (=*L. carinata* Lamarck), 1, Rio Reventado-Cartago, 812. "*Mactra*" in Olsson, 1922, p. 263, pl. 28, fig. 3. Escutcheon more deepened in this specimen (a cast) than in type of species.
18. *Labiosa* (*Labiosa*) *exoleta* (Gray)?, 1, Carballo, 830. "*Mactra*" in Olsson, 1922, p. 262, pl. 28, fig. 2.
19. *Mactra* (*Harvella*) *sincola* Olsson, 3, Carballo, 772; 4, locality?, 770, ex 779, ex 780.
20. *Mactra*(*Micromactra*) *macescens*(Guppy) var. *elongata* n. var., 1, locality?, 780. Described below. The type of the species was described and figured from the Manzanilla Miocene of Trinidad (see Guppy, 1866, p. 581, pl. 26, fig. 2; Maury, 1925, p. 113, pl. 21, fig. 1). Mentioned by Romanes (1912, p. 125) from the Barranca deposits at the Pacific coast of Costa Rica, northwest of Carballo.
21. *Pecten gatunensis* Toula?, 5, locality?, 764, 803; 1 Quebradas, 791.
22. *Pecten oxygonus* Sowerby, specimen transitional between subspec. *canalis* Brown and Pilsbry and sub spec. *optimus* Brown and Pilsbry, 1, Quebradilla-Cartago, 822. Exhibiting shape of former ornament of latter subspecies.
23. *Pecten oxygonus optimus* Brown and Pilsbry?, 1, Quebradilla-Cartago, 828; 1, Agua Caliente-Cartago, 818.
24. *Pecten* (*Patinopecten*) *propatulus* Conrad?, 4, Patarrá, 801, 817; 1, Agua Caliente-Cartago, 824. Hitherto known only from the Miocene of California, Oregon, Washington and British Columbia (see Arnold, 1906, p. 64, cum synon., pl. 7, fig. 1, pl. 9, figs. 1, 2; Dall, 1909, p. 112, pl. 15, figs. 1, 2, pl. 16, fig. 1).
25. *Pecten* (*Lyropecten*) *magnolia* Conrad, 1, locality?, 792. Hitherto known only from the lower Miocene of California (see Arnold, 1906, p. 77, cum synon., pl. 24, figs. 1, 2, pl. 25, fig. 1).
26. *Amusium* n. sp. innom., 1, Tablazo, 823.

SCAPHOPODA

27. *Dentalium* (*Dentalium*) *bocasense* Olsson, 1, Carballo, 833.

GASTROPODA

28. *Natica?* sp. indet. aff. *N.?* sp. indet.

Brown and Pilsbry, 1, Patarrá-San José, 813. (1911, p. 360, pl. 28, figs. 6, 7). The present specimen is far smaller than that of Brown and Pilsbry and has a distinct spiral ornament.

29. *Turritella altilira altilira* Conrad, 1, locality ?, ex 803. Recently made the typical form of his "*Turitella altilira* Stock" by Merriam (1941, p. 44).
30. *Turritella gatunensis* Conrad, subsp. *tarataranoides* n. subsp., 85 ±, locality ? 773.
31. *Crepitacella limonensis* Olsson, 9, locality ?, ex 773. See footnote to description of *Crepitacella altispira*, n. sp.
32. *Crepitacella altispira* n. sp., 28, locality ?, ex 773.
33. *Crepitacella* n. sp., indet., aff. *C. altispirae* n. sp., 1, locality ?, ex 773.
34. *Halia* cf. *americana* Olsson, 1, Carballo, 825. About twice as large as holotype; with fewer spiral threads on lower half of body whorl.
35. *Cancellaria* (*Trigonostoma*) cf. *plummeri* Olsson, 1, Carballo, 829. Spiral sculpture more strongly developed than in holotype; about 10 spiral ribs and finer threads and lines between them; specimen crushed.
36. *Conus musaensis* Olsson?, 1, Carballo, 831.

The scarcity of material and the poor preservation of many specimens, especially among the Pectinidae, account for the question marks which had to be added to some of the above identifications. For the same reasons none of the pelecypod hinges could be examined, and determinations had to be based solely upon external characters.

LOCALITIES AND FACIES

The chief locality, Carballo, together with Punta Carballo,[2] yielded 17 of the 36 forms listed (nos. 2–4, 6, 7, 9–14, 18, 19, 27, 34–36). According to the information given by Don Juvenal Valerio to Mr. Cecil Underwood, both localities are on the Pacific coast at the Rock of Carballo, which hangs over the old tracks of the San José-Puntarenas railroad.

The individuals for which no locality is given belong to 15 different forms, three of which (nos. 2, 9, 19) are also present at Carballo; of the 12 others, the matrix of four (nos. 1, 5, 8, 20) agrees fairly well with that of the Carballo fossils, being a calcareous shale, bluish on a fresh surface and buff when weathered. Moreover, two of these four forms (nos. 8, 20) and two others (nos. 15, 16) were embedded in pieces of rock which contained other forms also occurring at Carballo. It may thus be inferred that all of them (nos. 1, 5, 8, 15, 16, 20) are either from Carballo or, at least, from the same facies and horizon. Unfortunately there is no locality for the four species of little gastropods (nos. 30–33) all of which were recovered from a small mass of a shale very similar to that of Carballo, but representing a softer phase and shading to green.[3]

All the other localities listed are in the environs of the cities of San José and Cartago in the central part of the country, at altitudes between 1000 and 1500 m.:[4] Patarrá, Las Quebradas and Tablazo[5] are within a radius of about 4 miles from San José; Agua Caliente, Rio Reventado and Quebradillas within a range of 1–3 miles from Cartago. The fossils from some of these localities differ lithologically from those dealt with above, and some of them seem to represent other facies, if not other horizons. Thus the Pectens from Patarrá and Agua Caliente (nos. 23, pro parte, 24) are preserved in a coarse-textured, dark-gray limestone; those from unknown localities in a dark-gray, fine limestone (no. 803) or in a light-gray, almost white limestone (no. 797). Some of these limestones, especially those from Patarrá and Agua Caliente, may belong to the San Miguel limestone, described by Romanes (1912, p. 106) from these localities and erroneously considered Cretaceous by Hill

[2] This locality is given for one fragment only of *Clementia inoceriformis*, which is represented also by a better and more complete specimen from Carballo.

[3] The extraordinary variety and quick changes in lithological appearance of the Barranca sediments were stressed by Romanes (1912, p. 124).

[4] See inset, Map NC-17, "Millionth Map of Hispanic America" of the American Geographical Society.

[5] This mountain attains 1805 m. but that does not necessarily mean that no. 26 was found at such a great altitude.

(1898, p. 227). On the other hand, some Pectinidae from Quebradas (no. 21, pro parte) and Tablazo (no. 26) are preserved in shales very similar to those from Carballo.

GEOLOGICAL AGE

All the known species to which fossils of the present collection could be referred[6] are of Miocene age or, at least, range into the Miocene; there cannot, therefore, be any doubt as to the Miocene age of all the molluscs here dealt with.

The question, however, of the epoch within the Miocene period to which they are to be referred requires most careful consideration. As there is no reliable evidence for synchronism of the fossils from Carballo and from unknown localities agreeing lithologically with that locality (nos. 1–16, 18–20, 27, 30–36, altogether 27 forms among 36 listed in the table), on the one hand, and those definitely coming from other localities, representing other facies or even horizons, on the other, it may be advisable to consider both groups separately:

Most of the known forms of the first group (nos. 1, 2, 5, 6, 8, 10, 14, 15, 18, 19, 27, 34–36) were hitherto recorded from the Gatun formation of the Panama Canal Zone and Costa Rica, considered by Olsson (1922, p. 10) as being middle and upper Miocene, but restricted by Woodring (1928, table facing p. 41) to the middle Miocene. Those species of this group which were hitherto known only from other regions do not conflict with that age assignment. Of the two species from the Alum Bluff group of Florida, *Cardium* (*Cerastoderma*) *waltonianum* Dall occurs in the Shoal River formation, which is certainly middle Miocene, and *Gafrarium* (*Gouldia*) *erosum* Dall in the Chipola formation, referred to the lower Miocene by Maury (1917, table following p. 459), but thought by Mansfield (1936, p. 173, table 1) to be not older than Helvetian. It is true that Maury has assigned the Tamana Miocene of Trinidad, which has yielded *Cardium* (*Trachycardium*) *tamanense* Maury, to the lower Miocene as well as the Manzanilla Miocene of the same island, the horizon from which *Chione* (*Chione*) *walli* (Guppy) and *Mactra* (*Micromactra*) *macescens* (Guppy), represented in the present group by its new var. *elongata*, were described. However, this latter horizon has been subsequently referred to the middle Miocene by Woodring (1928, table facing p. 41). A fourth Trinidad species, *Chione* (*Anomalocardia*) *brasiliana* (Gmelin), ranges from the upper Miocene to the present time.

Two species, *Clementia inoceriformis* (Wagner) and *Chione* (*Lirophora*) *alveata* (Conrad), represented at Carballo and hitherto recorded from Maryland and New Jersey, and from Virginia respectively, are known from the middle Miocene Chesapeake group.

Moreover, the middle Miocene age of the Carballo assemblage is supported by the fact that species of the comparatively rare gastropod genus *Crepitacella*, to which the new species *C. altispira* and *C.* n. sp. ind. affin. *C. altispirae* are most closely related, occur in the Gatun formation, in the Bowden formation of Jamaica, and in the Cercado del Mao and Rio Gurabo formations of Santo Domingo, all of these occurrences being middle Miocene.

Thus nothing would prevent the writer from referring the Carballo assemblage to the Gatun fauna and from considering it as middle Miocene but Woodring's authority, as that author (1926, p. 36, 1928, p. 88) supposes the fossils from Carballo to be of lower Miocene age. It must, however, be kept in mind:

1, That, according to Romanes (1912, p. 123), Carballo Cliff "presents a vertical face over 100 feet high, and in it are exposed a great variety of sediments many of which are fossiliferous," so that the material from Carballo here dealt with might come from a higher horizon of that cliff than that examined by Woodring;

2, That Woodring (1928, p. 88) states that near David, Chiriqui Province, Panama, both molluscs referred by him to the lower Miocene and "an unmistakable Gatun fauna" have been found, and that the same might be true of Carballo as well, particularly since the Gatun fauna can, according

[6] In these remarks and in the following ones questioned (?) or approximate (cf.) identifications are treated as equal to those made without reservation.

to Woodring, "be traced on the Pacific side from Darien to Chiriqui";

3, That Woodring adds that the material from Carballo in the United States National Museum is "rather poorly preserved";

4, That it has not yet been completely identified, whereas the two only specimens from Carballo Cliff and from Caldera near Carballo tunnel (the latter broken and doubtful as to its identification) recorded by Woodring (1926, p. 36) as lower Miocene are referred by him to *Clementia dariena* (Conrad), known since 1856 from the middle Miocene Gatun fauna and generally considered to be one of its characteristic fossils.[7]

At any rate, it is hardly possible at the present time definitely to decide the question as to whether the fossils from Carballo —and those supposedly from the same horizon—are to be referred to the lower or to the middle Miocene without careful investigation and zonal collection in the field and a thorough study of the collections in the United States National Museum mentioned by Woodring. It may be added that the western Panama material, correlated by Woodring with that from Carballo, is estimated by him to amount to nearly 100 species.

In any case, the fossils from Carballo here dealt with give new evidence of a connection between the Atlantic and Pacific Oceans in the Miocene period, as assumed by Romanes (1912, p. 137),[8] by other authors quoted by Woodring (1926, p. 28, footnote 11), by Olsson (1922, p. 33) and by Woodring himself (1926, p. 28, for lower Miocene and 1928, p. 87, for middle Miocene). Should the reference of those fossils to the Gatun stage, as attempted above, be justified, the geographical range of the Gatun fauna, recorded first from localities of the Panama Canal Zone by Toula (1909) and by Brown and Pilsbry (1911–12), then from the Caribbean coastal plains of the provinces of Limon (Costa Rica) and Bocas del Toro (Panama) by Olsson (1922), later from Darien (E of the Gulf of Panama) and from the province of Chiriqui (Woodring, 1928, pp. 87–88), would appear to be expanded to the northwest as far as Puntarenas (Costa Rica).

The stratigraphic position within the Miocene of the fossils of the second group, collected at various localities in the Candelaria Highland, is even more uncertain, particularly since hardly any of the Pectinidae of the present collection could be fully identified with known species. However, specimen 22 of the faunal list, transitional between two subspecies of *Pecten oxygonus* Sowerby established by Brown and Pilsbry, seems to be referable to the Gatun stage, and the same may be true of *P. oxygonus optimus* Brown and Pilsbry?, and *P. gatunensis* Toula?. Also, one of the two Pectinidae of Pacific type (nos. 24, 25), *P.* (*Patinopecten*) *propatulus* Conrad?, occurring at Agua Caliente together with *P. oxygonus optimus*, can, perhaps, be correlated with the Gatun stage, its Californian stratigraphic range being, according to Arnold, "middle? and upper? Miocene." The other *Pecten* of Pacific character, *P.* (*Lyropecten*) *magnolia* Conrad, however, occurs in California in the lower Miocene and can, therefore, not be immediately correlated with the Gatun stage. On the other hand, *Labiosa* (*Labiosa*) cf. *alata* (Spengler) (no. 17) and *Turritella altilira altilira* Conrad (no. 29) are nearly or even fully identical with species already described from the Gatun fauna.

There is no certain evidence that all of the fossils found at different localities in the environs of San José and Cartago belong to the same horizon and it would, therefore, be precipitate to assign them to a certain epoch of the Miocene period. It may be worth noting that after Hill's (1898, p. 227) and Alfaro's (1911, pp. 128–129) finds of some Pectens in the Central Highland of Costa Rica, the fossils from there, identified in the present paper, give further evidence of the uplift of Miocene marine sediments to high altitudes, as pointed out, more generally, by Romanes (1912, p. 106).[9]

[7] Woodring (1926, p. 35) gives the type locality of *Clementia dariena* as "middle Miocene (Gatun formation), near Gatun, Panama Canal Zone."

[8] "It is probable, both from the fossils occurring in some of these beds and from the fact that marine Tertiary deposits cross the Atlantic-Pacific watershed between San José and Cartago, that there was free interoceanic connection during their deposition."

[9] "These mountains, situated almost in the center of the isthmus" (viz. the mountains of the Cero Candelaria) "afford many interesting geological problems, since there is a considerable number of formations represented; and in them I

RELATIONS TO MIOCENE FAUNAS OF OTHER REGIONS

Twenty of the 36 forms listed (nos. 1, 2, 5, 6, 8, 10, 14, 15, 17–19, 21–23, 27, 29, 31, 34–36) were described from the Gatun fauna in the papers of Brown and Pilsbry (1911, 12), Olsson (1922) and earlier authors.

Among the 16 others two (nos. 16, 28), which could not be specifically determined, must be eliminated from the outset. Two more, *Cardium* (*Cerastoderma*) *waltonianum* Dall (no. 3) and *Gafrarium* (*Gouldia*) *erosum* Dall (no. 13), were hitherto known from the Florida Miocene only; three more from the Miocene of Trinidad: *Cardium* (*Trachycardium?*) *tamanense* Maury (no. 4), *Chione* (*Chione*) *walli* (Guppy) (no. 9) and *Chione* (*Anomalocardia*) *brasiliana* (Gmelin) (no. 12), the latter species persisting throughout the Pliocene of Trinidad and Brazil and still living in Brazil, the West Indies and North Carolina. To these Caribbean types may be added four of the new forms described in the present paper: the new variety *elongata* of *Mactra* (*Micromactra*) *macescens* (Guppy), a species of the Trinidad Miocene (no. 20); the new subspecies *taratarana̲oides*, representing, in this collection, that most variable species *Turritella gatunensis* Conrad, s.l., an index fossil of the Gatun stage, and most closely related to its Venezuelan subspecies *taratarana* Hodson (no. 30); finally, *Crepitacella altispira*, n. sp., and *Crepitacella*, n. sp. ind. affin. *C. altispirae* n. sp. (nos. 32, 33), both of which have their nearest relations in the faunas of the Gatun stage (*Crepitacella limonensis* Olsson) and of Cumana, Venezuela?,[10] or, more probably, Bowden, Jamaica, and Santo Domingo (*Crepitacella cepula* (Guppy)). A good many Carribean forms appear thus to be represented in this Costa Rican collection as well as in the Gatun fauna studied by Olsson (1922, pp. 21–24).

On the other hand, two Pacific types are found in the present collection: *Pecten* (*Patinopecten*) *propatulus* Conrad? (no. 24) and *Pecten* (*Lyropecten*) *magnolia* Conrad (no. 25), both hitherto known from the Californian Miocene, the latter also from the Miocene of Oregon, Washington and British Columbia. It may be worth noting that neither of these species is present at the westernmost locality, Carballo, on the Pacific coast: the first has been found at two localities of the Central Highland, whereas the locality of the second is unknown but, to judge by its matrix, is not Carballo. This presence of a few Pacific types along with many Caribbean ones in the present material gives further evidence of an interoceanic connection in the Miocene period, as already stated, for the Gatun fauna, by Olsson (1922, p. 18).

Hardly less interesting is the presence, at Carballo, of two species hitherto known only from the Miocene of more northern parts of the Atlantic coast: *Clementia inoceriformis* (Wagner) (no. 6) and *Chione* (*Lirophora*) *alveata* (Conrad) (no. 11), the first from Maryland and New Jersey, the second from Maryland and Virginia. Should the correlation of the Carballo material with the Gatun fauna prove to be correct, these two species would increase to six the total number of forms common to the Gatun and to the Chesapeake group, four species having been listed by Olsson (1922, p. 31). The occurrence of these types in both faunas may be somewhat striking with regard to the usual conception of the Chesapeake fauna as a cold- or temperate-water fauna. On the other hand the extreme similarity, e.g., between *Clementia dariena*, a typical Central American form, and *Clementia inoceriformis*, till now thought to be confined to Maryland and New Jersey, as seen by comparing Palmer's (1927) pl. 25, fig. 13, and pl. 26, fig. 15, can hardly be overlooked, superficial as this resemblance may be, as both species are referred to different subgenera—C. *dariena* to *Clementia* s. str., *C. inoceriformis* to *Egesta* Conrad (cf. Woodring, 1926, pp. 32, 33, and 34–36, pl. 14, figs. 6–11; pp. 36–37, and 38–39, pl. 15, figs. 5, 6).

DESCRIPTIONS OF NEW FORMS

MACTRA (MICROMACTRA) MACESCENS (Guppy), var. ELONGATA Haas, n. var.

Text figure 1

Distinct from type of this species ("*Mactrinula*" *macescens* Guppy, 1866, p. 581, pl. 26, fig. 2; see also Maury, 1925, p. 113, cum

have been able to trace marine sediments to a height of at least 6000 feet above sea level."

[10] This locality is questioned by Woodring (1928, p. 361), who believes Guppy's type to come rather from Bowden, Jamaica.

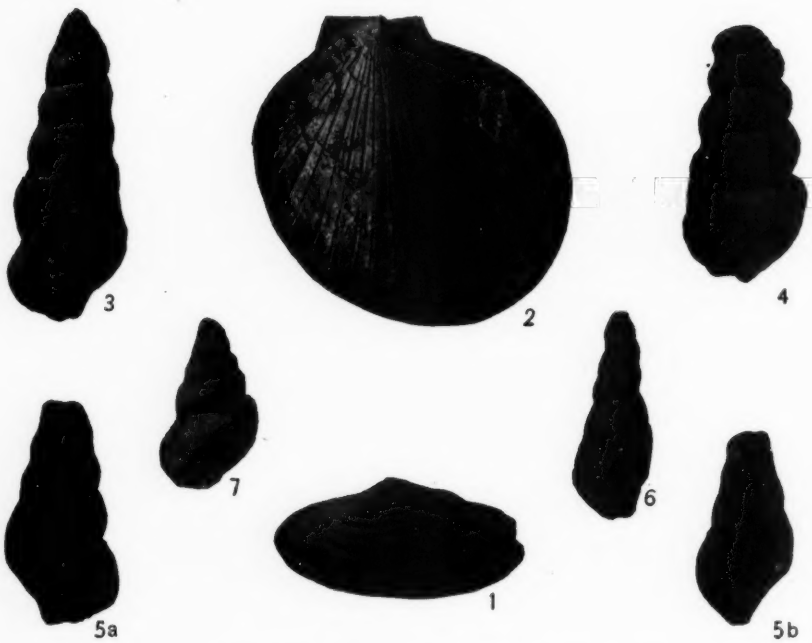

FIG. *1—Mactra (Micromactra) macescens* (Guppy) var. *elongata* Haas, n. var. Holotype, Field Mus. no. P 28915, ×1. (p. 313)
2—Amusium n. sp. innomin. Field Mus. no. P 28916, ×1. (p. 314)
3, 4—Turritella gatunensis Conrad subsp. *tarataranoides* Haas, n. subsp. *3*, Holotype, Field Mus. no. P 28908; *4*, paratype, no. P 28909; both ×1½. (p. 315)
5, 6—Crepitacella altispira Haas, n. sp. *5a, b*, Holotype, Field Mus. no. P 28910; *5a*, ×2.3; *5b*, ×2±. *6*, Paratype, no. P 28911, ×2.3. (p. 315)
7—Crepitacella n. sp. ind. aff. *C. altispirae*, Field Mus. no. P 28914, ×2. (p. 316)

synon., pl. 21, fig. 1) by its much greater length and more pronounced and narrower concentric ripples (about 15, not counting those on the umbo). The umbo and upper part of posterior margin were destroyed in the single specimen.

Length, 33 mm.; height, 18 mm.; semidiameter, about 6 mm. The hinge could not be examined.

Occurrence.—Probably Carballo, Costa Rica, middle Miocene.

Holotype.—Field Mus., no. P 28915.

AMUSIUM n. sp. innomin.
Text figure 2

Valve almost flat, suborbicular, inequilateral; point of umbo at about first third of length of valve. Both its lateral regions slightly depressed and smooth. Beak neatly separated from both auricles, slightly raised and pointed in its middle part, flat on the sides. Ears flat, almost equal in size, upper margins slightly rising from beak so as to form a very obtuse angle.

The only specimen is a cast with a few remnants of the shell; it shows shallow impressions of 19 very fine lirae, which are equally distant from each other in the central part of the valve, but arranged in pairs toward both anterior and posterior margins; even there the interval between two pairs of lirae is less than one and one-half times as broad as that between both lirae of one pair. Three or four threads are observable between the lirae.

Length 44 mm., height 41 mm., semidiameter about 1½ mm.

Hinge not examined. Left (?) valve unknown.

Occurrence.—Miocene, Tablazo, Costa Rica.

Figured Specimen.—Field Mus., no. P 28916, right (?) valve.

Remarks.—This species, although appar-

ently new, is not named, as one valve only is present. It differs from "*Pecten* (*Amusium*)" *sol* Brown and Pilsbry (1912, p. 513, pl. 24, figs. 1, 2) in being more inequilateral and in not having all its lirae arranged in pairs. The same differences may be noted in comparison with "*Pecten* (*Amusium*)" *luna* Brown and Pilsbry (1912, p. 514, pl. 23, fig. 1; Olsson, 1922, p. 205, pl. 17, fig. 1) which is, moreover, much more nearly circular in shape and more convex. *Amusium bocasense* Olsson (1922, p. 206, pl. 17, figs. 3, 4) is more symmetrical and has many more lirae.

TURRITELLA GATUNENSIS Conrad, subsp. TARATARANOIDES Haas n. subsp.
Text figures 3, 4

Turritella gatunensis s.l. is represented in the collection by some 85 individuals, all of which belong to the same local variant of Conrad's species. This variant does not quite agree with Conrad's (1856, p. 72, pl. 5, fig. 20) original *Turritella gatunensis* nor with any of the forms referred by later authors to this most variable species, but it is very closely related to Hodson's (1926, p. 25, pl. 18, figs. 5, 7) subsp. *taratarana* from Venezuela.

The Costa Rica specimens agree with the latter in dimensions and in the convex outline of the whorls, also in the beaded appearance of the spirals, which is, however, observable only if preservation permits. On the other hand, there are considerable differences which do not allow the reference of these specimens to Hodson's subspecies. Even in the best preserved ones no secondary or tertiary spirals, as seen in Hodson's figures, can be found. There are not more than 10 to 12 primary spirals on the body whorl, and 4 or 5 on each whorl of the spire. The latter are almost equal in strength, although the second and the third from above are sometimes slightly stronger than the others. The uppermost spiral keel forms a distinct subsutural shoulder and is separated from the second by an oblique, flat, sometimes slightly concave belt. The distance between this keel and the second is a little larger than that between the others. Very fine striae of growth can be seen, preservation permitting, throughout the shell.

Height of holotype (as far as preserved), 29 mm.; diameter, 11.4 mm. Height of paratype (as far as preserved), 23.5 mm.; diameter, 11.8 mm.

Occurrence.—Middle Miocene, Costa Rica.

Types.—Holotype (fig. 3), Field Mus., P 28908; paratype (fig. 4), P 28909.

CREPITACELLA ALTISPIRA Haas, n. sp.
Text figures 5, 6

The comparatively rare genus *Crepitacella* Guppy, 1867, is represented in this material by 38 individuals all of which were embedded in the same small piece of rock as all those referred to *Turritella gatunensis taratanoides*.[11] The new species here dealt with, represented by 28 specimens, occurs with *C. limonensis* (Olsson (1922, p. 143, pl. 15, fig. 17), described from the Gatun fauna.

The largest individuals of this elegant species attain almost 15 mm. in height and 7 mm. in diameter. From both *C. limonensis* and *C. cepula* (Guppy, 1866, p. 580, pl. 26, fig. 14)[12] as well as from the type of "*Dolophanes*" *melanoides* Gabb (see Pilsbry, 1922, pl. 34, fig. 12), considered by Woodring (1928, p. 361) to be a valid species, different from *C. cepula*, the new species is distinguished by a more slender shape and a body whorl considerably lower than the spire. Otherwise it agrees fairly well with Olsson's species. The most complete specimen (paratype, fig. 6) consists of six whorls. In the holotype (figs. 5 a, b) one of the radial riblets is reinforced so as to form a ridge, which is continuous across the last three whorls.

Height of holotype (as far as preserved), 12.6 mm.; diameter, 6.9 mm. Height of paratype, 12 mm.; diameter, 4.5 mm.

Occurrence.—Middle Miocene, Costa Rica.

Types.—Holotype (figs. 5 a, b), Field Mus., no. P 28910; paratype (fig. 6), P 28911.

[11] This accumulation of at least 125 little gastropods is worth noting (cf. Merriam, 1941, p. 17, on "*Turritella* communities"). Conditions of life at this spot were doubtless most favorable just to these little forms. It also may be noted how much larger *Turritella altilira* Conrad grew than did the closely related *T. gatunensis* and, particularly, the latter's local subspecies *taratara-noides*.

[12] *C. limonensis* is considered by Woodring (1928, pp. 361, 362), a synonym of *C. cepula*, erroneously spelled *capula* in Guppy's text, but quoted as *cepula* by all later authors, including Guppy and Dall (1897, p. 329), Maury (1917, p. 121, pl. 21, fig. 9), Olsson (1922, p. 143) and Woodring (1928, p. 361, pl. 28, figs. 1–3).

CREPITACELLA n. sp. indet. aff. C. ALTISPIRAE Haas, n. sp.
Text figure 7

A single almost complete specimen, consisting of 6½ whorls, is doubtless closely related to the preceding species, but it differs by its stouter body whorl and less acute spiral angle. Besides, it has radial riblets that are slightly less curved, broader and separated from each other by sharply limited furrows, which are as broad as the riblets.

Height, 11 mm.; diameter, 7 mm.

Although this form is apparently new the preservation of the single specimen is not adequate for the creation of a new species.

Occurrence.—Middle Miocene, Costa Rica.

Figured specimen.—Field Mus., no. P 28914.

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SILURIAN FORAMINIFERA OF THE MISSISSIPPI BASIN

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ABSTRACT—Seventy-nine species of arenaceous Foraminifera are described from the Silurian of the Mississippi Basin. They are classified into 5 families and 21 genera. One subfamily, Thekammininae, 4 genera, *Thekammina*, *Shidelerella*, *Croneisella* and *Gastroammina*, 57 species, and 2 varieties are new.

INTRODUCTION

THE SILURIAN fauna of the Mississippi Basin has been studied megascopically by Ball (1), Cumings (2), Foerste (3), Savage (4), Weller (5) and others, who have found it possible to correlate certain horizons over wide areas. There are other horizons, however, that are very difficult to work with either because of the absence of fossils or because of the dolomitization of the limestone. The Alexandrian of Ohio and eastern Kentucky (6) and the dolomitic Niagaran of the Chicago area are noted examples of strata of Silurian age that are difficult to correlate.

Late in the summer of 1930 I (7) discovered a faunule of arenaceous Foraminifera in the Bainbridge limestone of southeastern Missouri. This faunule is similar to that discovered by Moreman (8) in the Silurian Chimney Hill formation of Oklahoma. This similarity of faunas suggested the possibility of accurate Silurian correlation by the use of the microfauna alone.

Accordingly, I returned to the University of Chicago field camp in the summer of 1931 with full equipment for microscopic study. Almost every sample of Silurian rock reduced in acid contained arenaceous Foraminifera, some of which could be zoned at least as far as the major divisions of the Silurian.

On returning to the University of Chicago in the fall I examined a suite of 300 samples collected by Professor D. J. Fisher from a quarry at Joliet, Ill., in which both upper Alexandrian and lower Niagaran rocks were exposed. Many of the Foraminifera found in these samples were identical with those found in Missouri and Oklahoma.

Through the help of the Grants-In-Aid Committee of the National Research Council this study was continued in 1932 and 1933. It soon became apparent that definite zones could be traced over relatively wide areas. One of these zones, long considered devoid of index fossils, is found at the top of the Alexandrian in Illinois and Missouri. The age of this zone had been disputed, some geologists placing it in the Alexandrian, others in the Niagaran. It was found to contain definite index Foraminifera—so definite that it became an easy matter to determine its upper and lower boundaries in well cores and quarry exposures.

Thinking that this zone might be Osgood, I made a study of exposures in southern Indiana especially in the vicinity of Madison. In a new road cut in northern Kentucky across the Ohio river from Madison an excellent set of samples was collected. As the Osgood is well defined there, it was an easy matter to compare the Foraminifera with those found in the disputed zone in Illinois and Missouri. The index forms checked exactly, and thus the presence of the Osgood in northern Illinois and Missouri was established.

By this method the Brassfield, Osgood, and Laurel limestones were traced from Chicago to Nashville, Tenn., and from eastern Indiana to Oklahoma.

Though a thorough study of the upper part of the Silurian has not been made in all the areas mentioned, all samples from it were found to contain Foraminifera. It is therefore believed that the complete zoning of the Silurian can be accomplished by use of the arenaceous Foraminifera alone. A tentative correlation is shown in the table, and the range and distribution of the species in the list.

In the description of the species Cushman's (12) method is used in so far as it is applicable to arenaceous Foraminifera; the omission of the color character and the addi-

TENTATIVE CORRELATION OF SILURIAN STRATA IN THE MISSISSIPPI BASIN

		Indiana	Illinois	Tennessee	Missouri	Oklahoma
Silurian	Niagaran	Huntington	Port Byron	Lobelville	Bainbridge	?
		Louisville	Racine	Lego		Chimney Hill
		Waldron	Waukesha	Waldron		
		Laurel	Joliet	Laurel		
		Osgood	Osgood	Osgood	Osgood	Osgood
	Alexandrian	Brassfield	Brassfield (Kankakee)	Brassfield	Brassfield	Brassfield
			Edgewood		Edgewood	
			Girardeau		Girardeau	?
			Orchard Creek			

tion of the number, shape and position of the tubular openings being notable exceptions.

As the degree of cementation of the sand grains may not invariably be a safe character to follow, this characteristic is used with some hesitancy, for variation in the strength of acid used may make an apparent difference in the amount and strength of the cementing material.

A notable difference in the size of the sand grains may not warrant the erection of a new species, though if notable differences occur in specimens at the same locality with no intermediate stages, there might be some excuse for a separation into different species. If, however, different sizes occur at the same horizon but in different localities, the change may be due to the size of the sand grains available.

It has been found that the variation within certain species is very great, and many of these variations are figured. With added material some of these variations may prove to represent new species. Several new species are based upon only one individual, but only unusually well preserved specimens have been selected.

All types have been deposited in the collections of Walker Museum.

As this paper was made ready for press, a recent publication (10) by H. A. Ireland on Devonian and Silurian Foraminifera of Oklahoma has come to my attention. In this paper Mr. Ireland has listed a number of the species described in my unpublished thesis deposited in the library of the University of Chicago. As it has been found necessary to change the names and description of certain species and even to discard a few used in that original thesis, there are many discrepancies between the names in his lists and the species published here. Mr. Ireland has also given me credit for some species not mine. It is hoped that these discrepancies will in no way detract from the value of Mr. Ireland's excellent paper.

The writer wishes to express his indebtedness to Dr. Carey Croneis, under whose direction this work was carried on; to Dr. J. Harlan Bretz, Dr. D. J. Fisher, Dr. John R. Ball, Dr. M. M. Leighton, and Dr. W. H. Shideler for their helpful advice and cooperation in the collection of materials and to the National Research Council for its financial aid.

TECHNIQUE

The development of a technique (11) for breaking down both altered and unaltered limestones without destroying the Foraminifera was one of the most important parts of this study. Methods used by previous workers could not be applied to the highly calcareous limestones of the Missouri area or to the dolomitized limestones of the Chicago area. The greatest care must be taken to prevent the destruction of the more fragile Foraminifera, which are broken by even slight effervescence.

RANGE AND DISTRIBUTION OF SILURIAN FORAMINIFERA

Species	Edgewood	Brassfield	Osgood	Joliet	Bainbridge	Chimney Hill
Ammodiscus brevitubus			R			
Ammodiscus constrictus				R		
Ammodiscus exsertus			C	C	C	P
Ammodiscus furca			R			P
Ammodiscus incertus			C	C	C	P
Ammodiscus minutus			C			
Ammosphaeroides scotti			R			
Bathysiphon curvus		C	C	C	C	P
Bathysiphon exiguus			R	R	R	
Bathysiphon parallelus			R			
Colonammina bituba					C	
Croneisella typa		R	R			
Gastroammina williamsae			R			
Hyperammina hastula			C			
Hyperammina sublaevigata				C	C	
Lagenammina bulbosa		R	R			
Lagenammina sphaerica			C	C	C	P
Lagenammina stilla			R	C	C	P
Lagenammina urniformis			R			
Lituotuba elongata			C			
Lituotuba exserta			C	C	C	P
Lituotuba? furca				R		
Lituotuba salinensis			C			
Psammosphaera arcuata		C				
Psammosphaera cava	C	C	C	C	C	P
Psammosphaera conjunctiva			C			
Psammosphaera excerpta			C			
Psammosphaera gigantea			C			
Psammosphaera minuta				C	C	
Psammosphaera subsphaerica				C	C	
Proteonina acuta			R			
Proteonina jolietensis		C				
Proteonina? ovata		R				
Pseudastrorhize irregularis	R		R			
Pseudastrorhize regularis		R	R			
Raibosammina aspera			R			
Shidelerella bicuspidata			R			
Shidelerella cylindrica					R	
Shidelerella elongata					R	
Sorosphaera bicella		C	C	C	C	
Sorosphaera multicella					R	
Sorosphaera subconfusa						C
Sorosphaera tricella				C	C	C
Stegnammina cylindrica var.				R	C	
Thekammina moremani				R		
Thekammina quadrangularis				R		
Tholosina? dubia						C
Tolypammina tortuosa				C		
Thurammina arcuata					R	
Thurammina coronata				R		
Thurammina echinata					R	C
Thurammina elliptica				C		
Thurammina foerstei				R		
Thurammina? hexactinellida			C	C	R	
Thurammina hexagona					C	
Thurammina inflata						R
Thurammina irregularis				C	C	C
Thurammina jubata					R	R
Thurammina limbata						R
T. limbata var. disciformis				R		
Thurammina magna					C	
Thurammina melleni						C
Thurammina papillata					C	
T. papillata var. monticulifera					C	
Thurammina parrituba					C	
Thurammina phasela					C	
Thurammina quadrata						R
Thurammina quadritubulata						C
Thurammina? seminaformis				C		
Thurammina slocomi					C	
Thurammina splendens						R
Thurammina stelliformis						R
Thurammina subsphaerica						C
Thurammina triangularis					R	
Thurammina trituba					R	
Thurammina tubulata					C	C
Turritellella fisheri					C	R
Turritellella osgoodensis					C	
Turritellella workmani					C	

R—Rare C—Common P—Present

The most important step in the process is the determination of the correct strength of acid to be used for a given type of limestone. When there is only a small sample to work with, the slightest mistake may destroy all available material. A safe method is to place part of the sample, about one cubic inch, if possible, in a beaker or large tumbler and add water until the container is three-fourths full. There should be at least 10 times as much water as the space occupied by the sample, and even a greater proportion of water is desirable. Hydrochloric acid is added very slowly. The C. P. grade has been found to give better results than the commercial grade, since the latter will often cause a harmful precipitate of gypsum. A strength of 40 parts of water to 1 part acid is usually sufficient. After adding a small amount of acid to the water it is best to wait a few minutes until the temperature of the solution rises, since this rise in temperature aids in the breaking down process and must be taken into consideration

before adding more acid.

If the sample is small, greatest care must be used to prevent the destruction of the specimens that have been freed from the matrix. When raw acid is poured into the beaker it sinks to the bottom, and the unprotected specimens are bathed with acid strong enough to break down many of them. The residue should therefore be washed before any fresh acid is added. The part of the sample that has not been reduced is carefully lifted out; if it is to be further reduced, it may be placed in a clean beaker and the surplus liquid poured onto it.

The residue is carefully washed into an evaporating dish. The strong current from a faucet should not be allowed to strike the residue, for the specimens are easily broken. A slow process of washing and decanting should be employed until the water is perfectly clear. All the water is poured off with the exception of a sufficient amount to wash out the residue on a square of paper. Ordinary newspaper has been found to give better results in this drying process than a harder or rougher paper. The wet residue will stick to the newspaper, and the surplus water can be poured off. If rough paper like toweling is used, the dry residue cannot be removed without breaking the specimens.

The residues should be dried very slowly. Drying over a fire, even with a sand bath, is likely to destroy the specimens. It has been found satisfactory to dry the residue in the evaporating dish itself when no fine mud is present.

Some workers in this field have suggested the sorting of specimens while they are immersed in water. This is not a satisfactory method because the specimens of colorless quartz are inconspicuous under water and very difficult to pick up. A small brush trimmed to a sharp point is the only instrument which has proved satisfactory in the handling of these delicate objects. After touching the brush to the tip of one's tongue the specimens may be picked up without injury, but if water is used instead of saliva the dry specimens are more apt to be broken. A gum tragacanth solution of the correct consistency has been found to be the best mounting material.

As the acid method destroys the calcareous individuals, it is probable that many faunal lists would be greatly increased by the development of a technique for the preparation of calcareous forms. Although thin sections have not shown the presence of calcareous Foraminifera in the samples used in the study, other calcareous microfossils are very abundant in some of them.

LOCALITIES

1. Exposure along Ozora-St. Marys road, Ste. Genevieve County, Mo., about 2 miles southeast of Ozora, where the road turns sharply northward toward the Greither Hills.
2. Exposure at University of Chicago Field Station, Ste. Genevieve County, Mo.
3. Exposure in bed of Little Saline Creek just west of the point where the Ozora-St. Marys road crosses the Creek.
4. Exposure south of the western end of Peachtree Ridge at a point where the northwest-southeast fault crosses the Ozora Staabtown road, Ste. Genevieve County, Mo.
5. Five miles south of St. Marys and ¼ mile west of Lithium Springs, Perry County, Mo.
6. In the village of Lithium Springs, Perry County, Mo.
7. One mile south of Ozora, along the Ozora-St. Marys road. The exposure is 200 yards east of the road and on the south slope of Lipp Hill, Ste. Genevieve County, Mo.
8. Gecht farm, 2 miles south of Staabtown, Ste. Genevieve County, Mo.

1001. Quarry of the Joliet Stone Co. in the southwest section of the town of Joliet, Will County, Ill.

1002. Quarry of the National Stone Co., southeast section of Joliet.

1003. Two miles east of Richy, Will County, Ill., along Forked Creek.

1004. Two miles east of Wilmington, Will County, Ill., along Jordan Creek.

1005. Five miles south of Joliet along Jackson Creek.

1006. Two miles south of Blodget, Will County along the Kankakee River.

1007. Deloese and Shepard quarry, western edge of Chicago, Ill.

1008. Two and one-half miles southwest of Joliet on the southeast side of Des Plaines River.

1009. South bank of the Kankakee River about 4½ miles below Wilmington, Ill.

1010. North bank of the Kankakee River, sec. 27, T. 32 N., R. 10 E.

1011. Sec. 14, ½ mile south of Millsdale, Ill.

1012. Five miles south-southeast of Joliet along Jackson Creek.

1013. Four miles southwest of Joliet, Ill., in sec. 35.

2001. Osgood quarry, Osgood, Ind.

3001. Road cut across the Ohio river from Madison, Ind.

4001. Road cut along Memphis-Nashville highway, 14 miles west of Nashville.

DESCRIPTION OF SPECIES

Order FORAMINIFERA

Family ASTRORHIZIDAE Brady, 1881

Test free, consisting of a central chamber from which radiate tubular channels to the exterior, either simple or branching; wall with a thin chitinous inner layer, on all or part of which is agglutinated arenaceous material; apertures formed by the peripheral ends of the arms or by openings in the peripheral wall.

Genus PSEUDASTRORHIZA Eisenack, 1932

Pseudastrorhiza EISENACK, *1932*, Palaeont. Zeitschr., vol. 14, p. 259.
Pseudastrorhiza, CUSHMAN, *1933*, Foraminifera, 2d ed., p. 68.

Genotype, *Pseudastrorhiza silurica* Eisenack.

Cushman's description.—Test free, very similar to *Astrorhiza*, with a central chamber and several radiating arms in varying planes; wall thin, of fine sand grains; apertures not apparent. Silurian of the Baltic region.

There may be as many as seven arms to the test. This is the oldest known genus of the *Astrorhizidae* as yet discovered. It probably had a chitinous base to hold together the thin arenaceous wall.

Remarks.—Eisenack hesitates to put this genus in the *Astrorhizidae* because of the absence of apertures. Cushman, however, seems to value the general shape more than the presence or absence of apertures and places the genus in the *Astrorhizidae*. This writer is inclined to take Cushman's view.

PSEUDASTRORHIZA IRREGULARIS Dunn, n. sp. Plate 42, figure 2

Test free, with radiating arms, which are irregular in position and number; arms both branched and unbranched, numbering eight on the figured specimen, with six on the periphery and two pointing upward; wall of rather large sand grains loosely cemented; apertures not apparent.

Dimensions.—Average diameter of central portion, 0.4 mm.; average length of tubes, 0.25 mm.

Occurrence.—Edgewood limestone, Illinois, locality 1013.

Remarks.—The arms are more slender on this species than on *P. silurica* Eisenack. Found in the lower part of the Osgood in Missouri.

Holotype.—Walker Museum, no. 48,400.

PSEUDASTRORHIZA REGULARIS Dunn, n. sp. Plate 42, figures 3, 4

Test free, with radiating arms, which are regular in position and number, having five arms evenly spaced around the periphery and, equidistant from their bases, a sixth, which extends outward from the upper, more convex surface of the test; wall of rather large sand grains loosely cemented; apertures not apparent.

Dimensions.—Average diameter of central portion, 0.26 mm.; average length of tubes, 0.2 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001 (fig. 3); Brassfield limestone, Illinois, locality 1001 (fig. 4).

Remarks.—This species differs from *P. irregularis* only in the regularity of the position and number of the arms. A broken specimen was found in the Brassfield of Missouri.

Holotype.—Walker Museum, no. 48,401; paratype, 48,402.

Family RHIZAMMINIDAE Brady, 1879

Test consisting of a tubular chamber open at both ends; wall with a chitinous lining and exterior of agglutinated foreign material, arenaceous grains, sponge spicules or other Foraminifera; apertures formed by the open ends of the tubes.

Genus BATHYSIPHON M. Sars, 1872

Bathysiphon M. SARS, *1872*, in G. O. Sars, Vidensk.-Selsk. Christiania Forh., 1871, p. 251.
Bathysiphon, CUSHMAN, *1928*, Foraminifera, p. 67.

Cushman's description.—Test free, cylindrical, often tapering slightly, straight or more often somewhat curved, in some species externally constricted but not internally divided; wall composed of a base of broken sponge spicules cemented and overlaid with a fine grained amorphous material, either soft or firmly cemented, often with a very thin surface coating; apertures at the ends of the tube.

Remarks.—It is difficult to separate this genus from *Hyperammina* unless the specimen is unbroken. It is also difficult to separate the species on fragments alone.

BATHYSIPHON CURVUS Moreman
Plate 42, figure 5

Bathysiphon curvus W. L. MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 45.

Moreman's description.—Test free, cylindrical, curved and distinctly tapering, in some specimens very slightly constricted at intervals; wall thin, composed mostly of very fine sand firmly cemented, surface smooth; apertures at the ends of the tube; color white. Length of specimens, 1.4 and 1.2 mm.

Dimensions.—Length of figured specimen, 1.23 mm.; diameter, 0.08 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—The specimen figured here is somewhat more pointed than those figured by Moreman, but the typical constrictions are present. Common in Brassfield and Niagaran.

Hypotype.—Walker Museum, no. 48,403.

BATHYSIPHON EXIGUUS
Moreman
Plate 42, figure 27

Bathysiphon exiguus MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 46.

Moreman's description.—Test free, cylindrical, slightly tapering, straight and very small; wall thin, composed of fine sand cemented, surface smooth; apertures at the open ends of the tubes; color white. Length 0.25 mm.

Dimensions.—Length of figured specimen, 0.42 mm.; diameter, 0.10 mm.

Occurrence.—Niagaran, Illinois, locality 1007.

Remarks.—As the specimen is broken, it is difficult to determine the exact species. The straightness of the test led the writer to assign it to this species. Fragments of this size and shape are common in the Brassfield, but no complete specimens were found. Uncommon in Niagaran.

Hypotype.—Walker Museum, no. 48,404.

BATHYSIPHON PARALLELUS
Dunn, n. sp.
Plate 42, figure 1

Test free, cylindrical, curved, diameter regular, externally constricted; wall thin, composed of fine sand firmly cemented, surface smooth but slightly uneven due to constrictions; constricted apertures at either end of test.

Dimensions.—Length, 1.23 mm.; diameter, 0.08 mm.

Occurrence.—Osgood limestone, Missouri, locality 1.

Remarks.—Since this species does not taper toward one end it can be separated easily from *B. curvus* unless the specimen is broken.

Holotype.—Walker Museum, no. 48,405.

Family SACCAMMINIDAE
Brady, 1884?

Test free or attached, composed typically of a single chamber or occasionally with chambers of the same sort loosely united; wall lined with chitin, the exterior of agglutinated material of various sorts, sand grains, sponge spicules or other foraminiferal tests; aperture usually single, of various shapes.

Remarks.—The meaning of the word "single" is not clear. It may mean one aperture instead of a number of apertures or a single instead of a double aperture. The writer accepts the former meaning. Single apertures, however, are not the rule as far as the species of this family here described. The majority of species belong to the genus *Thurammina* and have two or more apertures.

Subfamily PSAMMOSPHAERINAE
Cushman

Test spherical or subspherical, without a definite aperture.

Genus PSAMMOSPHAERA Schultze, 1875

Psammosphaera SCHULTZE, *1875*, II Jahr. Comm. Wiss. Unt. deutsch. Meer in Kiel, p. 113.
Psammosphaera, CUSHMAN, *1928*, Foraminifera, p. 71.

Cushman's description.—Test free or attached, globular, wall composed of a thin layer of chitin with an outer wall of sand grains, mica flakes, sponge spicules or other foraminiferal tests, firmly cemented; aperture indefinite.

Remarks.—There are numerous variations in this genus. It may be found on further study that some of the species described under it may belong to a new genus.

PSAMMOSPHAERA CAVA Moreman
Plate 42, figure 6

Psammosphaera cava MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 48.

Moreman's description.—Test free, spherical; wall thin, composed mostly of fine sand grains, well cemented; aperture indefinite; color white. Diameter, 0.5 mm.

Dimensions.—Diameter of figured specimen, 0.39 mm.

Occurrence.—Osgood limestone, Missouri, locality 5.

Remarks.—The specimen figured differs from Moreman's in having walls of coarse sand grains, some of which are not very well cemented. Common in Alexandrian and Niagaran.

Hypotype.—Walker Museum, no. 48,406.

PSAMMOSPHAERA ARCUATA
Dunn, n. sp.
Plate 42, figures 14a, 14b, 24

Test free, compressed laterally to give an arcuate appearance; wall of medium thickness, composed of medium to fine sand grains well cemented; aperture indefinite.

Dimensions.—Figure 14, 0.38 by 0.30 by 0.22 mm.; figure 24, 0.66 by 0.50 by 0.44 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001.

Remarks.—This species is similar in shape to *Thurammina arcuata*, but the lack of tubes and apertures excludes it from that genus and species. Common in the Brassfield of Illinois.

Holotype.—Walker Museum, no. 48,407; paratype, 48,408.

PSAMMOSPHAERA CONJUNCTIVA
Dunn, n. sp.
Plate 42, figure 28

Test attached, subspherical; wall thin, composed of medium to fine sand grains, well cemented; aperture indefinite.

Dimensions.—Greatest diameter, 0.34 mm.; shortest diameter, 0.24 mm.

Occurrence.—Osgood limestone, Missouri, locality 6.

Remarks.—Rather common in the Osgood of Missouri.

Holotype.—Walker Museum, no. 48,409.

PSAMMOSPHAERA EXCERPTA
Dunn, n. sp.
Plate 42, figures 7, 8

Test free, spherical; commonly small; wall thick, composed of large sand grains of uniform size, well cemented; aperture indefinite.

Dimensions.—Diameters of figured specimens: figure 7, 0.20 mm.; figure 8, 0.26 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001. Common in the Osgood.

Remarks.—Recognized by its small size and large sand grains.

Holotype.—Walker Museum, no. 48,410; paratype, 48,411.

PSAMMOSPHAERA GIGANTEA
Dunn, n. sp.
Plate 42, figure 9

Test free, spherical, very large; wall thin, composed of fine sand grains well cemented; aperture indefinite.

Dimensions.—Diameter, 0.75 mm.

Occurrence.—Osgood limestone, Tennessee, locality 4001.

Remarks.—Specimens are common at type locality. Specimens that may belong to the same species are found in the Brassfield of Illinois. The Illinois specimens, however, have thinner walls, which are composed of very fine sand grains.

Holotype.—Walker Museum, no. 48,412.

PSAMMOSPHAERA MINUTA
Dunn, n. sp.
Plate 42, figures 10–12

Test free, spherical; commonly small; wall of medium thickness, composed of fine sand grains, well cemented, surface smooth; aperture indefinite.

Dimensions.—Average diameter, 0.23 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The species differs from *P. cava* in its small size and smoother surface. It is much smoother than *P. excerpta*. Figure 12 is a very small specimen and may not belong to this species.

Holotype.—Walker Museum, no. 48,413; paratypes 48,414 and 48,415.

PSAMMOSPHAERA SUBSPHAERICA
Dunn, n. sp.
Plate 42, figure 13

Test free, compressed on one side to give a distinct flattened base; wall of medium thickness, composed of medium to fine sand grains well cemented; aperture indefinite.

Dimensions.—Greatest diameter, 0.32 mm.; shortest diameter, 0.25 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—This flattened character is too common to be the result of an accident.

Holotype.—Walker Museum, no. 48,416.

Genus SOROSPHAERA Brady, 1879

Sorosphaera BRADY, *1879*, Quart. Jour. Micr. Sci., vol. 19, p. 28.
Sorosphaera, CUSHMAN, *1928*, Foraminifera, p. 72.

Cushman's description.—Test consisting of a group of more or less inflated chambers, in an aggregate; wall with a chitinous lining and the exterior of fine sand grains; apertures minute, interstitial.

Remarks.—There is great variation in size, number, and arrangement of chambers in this genus. The aggregate may have a flat base.

SOROSPHAERA TRICELLA Moreman
Plate 42, figure 15

Sorosphaera tricella MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 49.

Moreman's description.—Test composed of three more or less spherical chambers attached in the same plane but each apparently independent of the others, the aggregate free; wall thin, composed of fine sand with much cement, surface smooth; apertures not apparent; color yellow or brownish. Diameter of individual chambers 0.18 and 0.36 mm.

Dimensions.—Diameter of the individual chambers of figured specimen, 0.22 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The specimens that seem to belong to this species have considerable

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EXPLANATION OF PLATE 42

All figures ×35

FIG. *1*—*Bathysiphon parallelus* Dunn, n. sp. Locality 1; Walker Museum, no. 48,405. (p. 322)
2—*Pseudastrorhiza irregularis* Dunn, n. sp. Locality 1013; Walker Museum, no. 48,400. (p. 321)
3, 4—*Pseudastrorhiza regularis* Dunn, n. sp. Locality 1001; Walker Museum. *3*, No. 48,401. *4*, no. 48,402. (p. 321)
5—*Bathysiphon curvus* Moreman. Locality 1001; Walker Museum, no. 48,403. (p. 322)
6—*Psammosphaera cava* Moreman. Locality 5; Walker Museum, no. 48,406. (p. 322)
7, 8—*Psammosphaera excerpta* Dunn, n. sp. Locality 1001; Walker Museum. *7*, no. 48,410. *8*, no. 48,411. (p. 323)
9—*Psammosphaera gigantea* Dunn, n. sp. Locality 4001; Walker Museum, no. 48,412. (p. 323)
10–12—*Psammosphaera minuta* Dunn, n. sp. Locality 1; Walker Museum. *10*, no. 48,413. *11*, no. 48,414. *12*, no. 48,415. (p. 323)
13—*Psammosphaera subsphaerica* Dunn, n. sp. Locality 1; Walker Museum, no. 48,416. (p. 323)
14a, b—*Psammosphaera arcuata* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,407. (p. 323)
15—*Sorosphaera tricella* Moreman. Locality 1; Walker Museum, no. 48,417. (p. 324)
16—*Sorosphaera subconfusa* Dunn, n. sp. Locality 1; Walker Museum, no. 48,421. (p. 325)
17, 18—*Sorosphaera bicella* Dunn, n. sp. *17*, Locality 1; Walker Museum, no. 48,418. *18*, Locality 1001. (p. 325)
19a, b—*Sorosphaera multicella* Dunn, n. sp. Top and lateral views. Locality 2001; Walker Museum, no. 48,419. (p. 325)
20—*Sorosphaera subconfusa* Dunn, n. sp. Locality 1; Walker Museum, no. 48,420. (p. 325)
21—*Lagenammina bulbosa* Dunn, n. sp. Locality 1009; Walker Museum, no. 48,432. (p. 326)
22—*Thekammina moremani* Dunn, n. sp. Locality 7; Walker Museum, no. 48,425. (p. 326)
23—*Thekammina quadrangularis* Dunn, n. gen. n. sp. Locality 1001; Walker Museum, no. 48,424. (p. 326)
24—*Psammosphaera arcuata* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,408. (p. 323)
25—*Stegnammina cylindrica*, var. *brevis*, Dunn, n. var. Locality 7; Walker Museum, no. 48,422. (p. 325)
26—*Lagenammina bulbosa*, Dunn, n. sp. Locality 1001; Walker Museum, no. 48,433. (p. 326)
27—*Bathysiphon exiguus* Moreman. Locality 1007; Walker Museum, no. 48,404. (p. 322)
28—*Psammosphaera conjunctiva* Dunn, n. sp. Locality 6; Walker Museum, no. 48,409. (p. 323)
29—*Lagenammina sphaerica* Moreman. Locality 4; Walker Museum, no. 48,429. (p. 327)
30, 31—*Lagenammina stilla* Moreman. Locality 1001; Walker Museum. *30*, No. 48,430; *31*, no. 48,431. (p. 327)
32, 33—*Shidelerella elongata* Dunn, n. sp. Locality 2; Walker Museum. *32*, no. 48,437. *33*, no. 48,438. (p. 329)

Dunn, Silurian Foraminifera

variation. Common in both the Brassfield and the Niagaran.

Holotype.—Walker Museum, no. 48,417.

SOROSPHAERA BICELLA Dunn, n. sp.
Plate 42, figures 17, 18

Test free, composed of two more or less spherical chambers; wall thin, composed of medium to fine sand; surface commonly smooth; aperture not apparent.

Dimensions.—Diameters of individual chambers in figured specimens, 0.26 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1 (fig. 17). Brassfield limestone, Illinois, locality 1001 (fig. 18).

Remarks.—Common in Brassfield and Niagaran.

Holotype.—Walker Museum, no. 48,418.

SOROSPHAERA MULTICELLA
Dunn, n. sp.
Plate 42, figures 19a, b

Test free, composed of a ring of six spherical chambers in one plane and a seventh resting on the center of the group; base of the aggregate distinctly flattened (see fig. 19b). Wall thin, composed of fine sand, well cemented; aperture not apparent.

Dimensions.—Diameter of individual chamber, 0.20 mm.

Occurrence.—Waldron formation, Waldron, Ind., locality 2001.

Remarks.—The number of chambers may vary in this species.

Holotype.—Walker Museum, no. 48,419.

SOROSPHAERA SUBCONFUSA
Dunn, n. sp.
Plate 42, figures 16, 20

Test free, composed of an indefinite number of spherical chambers usually in one plane with no definite arrangement; wall thin, composed of fine sand grains, well cemented; aperture not apparent.

Dimensions.—Diameter of individual chambers in figured specimens, 0.18 mm.

Occurrence.—Osgood limestone, Missouri, locality 1.

Remarks.—The black spots are broken parts of the tests, not apertures. Common in Osgood of Missouri.

Holotype.—Walker Museum, no. 48,420 (fig. 20); paratype 48,421.

Subfamily STEGNAMMININAE Moreman

Test free or attached, cylindrical or subcylindrical, either straight or irregularly branched; without a definite aperture.

Genus STEGNAMMINA Moreman, 1930

Stegnammina MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 49.

Moreman's description.—Test free, a straight cylindrical or subcylindrical chamber; wall thin, composed of small to medium sized sand grains, well cemented; aperture indefinite. Genotype *Stegnammina cylindrica* Moreman.

STEGNAMMINA CYLINDRICA BREVIS Dunn, n. var.
Plate 42, figure 25

Test free, cylindrical, ends slightly flattened; wall thin, composed of fine sand grains, well cemented, surface smooth; aperture not apparent.

Dimensions.—Length, 0.40 mm.; diameter, 0.22 mm.

Occurrence.—Brassfield, Missouri, locality 7.

Remarks.—The variety differs from typical *S. cylindrica* in being only half as long. Uncommon.

Holotype.—Walker Museum, no. 48,422.

Genus RAIBOSAMMINA Moreman, 1930

Raibosammina MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 50.
Raibosammina, CUSHMAN, *1933*, Foraminifera, 2d ed., p. 74.

Genotype, *Raibosammina mica* Moreman.

Cushman's description.—Test free or attached, subcylindrical, straight, crooked, or irregularly branched, interior of chamber not of uniform diameter; wall of unequal thickness, composed of poorly sorted sand grains; aperture not apparent.—Lower Paleozoic, America.

RAIBOSAMMINA ASPERA
Moreman
Plate 44, figure 1

Raibosammina aspera MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 50.

Moreman's description.—Test free, subcylindrical; chamber crooked and irregularly branched, interior irregular in diameter; wall of uneven thickness, composed of poorly sorted material, surface rough; aperture not apparent; color white or brownish.

Length of figured specimens, 1.44, 0.7 and 1 mm.

Occurrence.—Viola limestone. Locality No. 1.

Dimensions.—Length, 1.15 mm.; average diameter, 0.19 mm.

Occurrence.—Osgood limestone, Missouri, locality 1001.

Remarks.—Numerous specimens of irregular sizes and shapes were found that may belong to this genus and perhaps to the species.

Holotype.—Walker Museum, no. 48,423.

Subfamily THEKAMMININAE Dunn, n. subfam.

Test free or attached, with walls compressed to give an angular outline; never spherical or cylindrical; unbranched.

Genus THEKAMMINA Dunn, n. gen.

Test free, with walls compressed to give an angular outline; varying from a flattened triangular to a box-shaped test; wall thin, composed of fine to coarse sand grains, usually poorly cemented; aperture indefinite.

Genotype *Thekammina quadrangularis* Dunn, n. gen., n. sp.

The meaning of the name is "sandy box."

THEKAMMINA QUADRANGULARIS Dunn, n. gen., n. sp.
Plate 42, figure 23

Test free, box-shaped; wall thin, composed of rather coarse sand grains, poorly cemented; aperture indefinite.

Dimensions.—Longest diameter, 0.39 mm.; shortest diameter, 0.28 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001.

Remarks.—Not common.

Holotype.—Walker Museum, no. 48,434.

THEKAMMINA MOREMANI Dunn, n. sp.
Plate 42, figure 22

Test free, depressed, triangular in outline; wall thin, composed of fine sand grains, well cemented; aperture indefinite.

Dimensions.—Diameter from point of triangle to middle of opposite side, 0.30 mm.

Occurrence.—Brassfield limestone, Missouri, locality 7.

Remarks.—This species is not to be confused with *Stegnammina triangularis*. Both species have a triangular outline, but *S. triangularis* is elongated and *T. moremani* depressed. This species is rare.

Holotype.—Walker Museum, no. 48,425.

Subfamily SACCAMMININAE

Test free, with a definite aperture; wall of firmly agglutinated sand, sponge spicules, or other objects, usually not thick nor with fine white amorphous material.

Genus PROTEONINA Williamson, 1858

Proteonina WILLIAMSON, *1895*, Rec. Foram. Great Britain, p. 1.
Reophax (part) of authors.
Diffugia EGGER, *1895* (not Lecheric, 1815).
Saccammina (part) ELMER and FICKERT, *1899*.
Proteonina, CUSHMAN, *1933*, Foraminifera, 2d ed., p. 74.

Genotype, *Proteonina fusiformis* Williamson.

Cushman's description.—Test free, a fusiform or flask-shaped undivided chamber; wall a thin chitin layer on which are cemented sand grains, mica flakes, other tests, etc.; aperture usually circular, often with a slight neck which may become elongate.—Carboniferous to Recent.

It is possible that *Brachysiphon* Chapman may belong here.

The genus *Archaelagena* Howchin is very obscure as to its real characters, and needs further investigation.

PROTEONINA JOLIETENSIS Dunn, n. sp.
Plate 43, figure 2

Test free, flask-shaped, with that part of the chamber nearest the aperture somewhat constricted but not enough to form a neck; wall thin, composed of fine sand grains; surface smooth; aperture terminal.

Dimensions.—Length, 0.26 mm.; diameter, 0.16 mm.

Occurrence.—Brassfield limestone, Illinois locality 1001.

Remarks.—Common near the top of the Brassfield in Illinois.

Holotype.—Walker Museum, no. 48,426.

PROTEONINA ACUTA Dunn, n. sp.
Plate 43, figure 3

Test free, flask-shaped, without neck but with upper portion sloping regularly towards the aperture to give a cone-shaped ap-

pearance; wall thin, composed of fine sand grains, well cemented; surface smooth; aperture at apex of cone.

Dimensions.—Length, 0.36 mm.; diameter, 0.24 mm.

Occurrence.—Osgood limestone, Illinois, locality 1002.

Remarks.—Uncommon.

Holotype.—Walker Museum, no. 48,427.

PROTEONINA? OVATA Dunn, n. sp.
Plate 43, figure 6

Test free, subovate in shape, with lower portion somewhat pointed and upper portion sloping towards a short neck; wall thin, composed of fine sand grains, well cemented; surface smooth; aperture at end of neck.

Dimensions.—Length with neck, 0.40 mm.; greatest diameter, 0.22 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001.

Remarks.—The neck is bent and may not be in its natural position. This species may belong to the genus *Shidelerella*.

Holotype.—Walker Museum, no. 48,428.

Genus LAGENAMMINA Rhambler, 1911

Lagenammina RHAMBLER, *1911*, Foram. Plankton-Exped., Pt. 1, p. 92.
Lagenammina, CUSHMAN, *1928*, Foraminifera, 1928, p. 73.

Cushman's description.—Test free, bottle-shaped, with a distinct pseudochitinous substratum on which are foreign bodies usually covering the under layer; aperture circular, at the end of an elongate neck.

Remarks.—The term "bottle-shaped" is not very definite, for all variations from bottle-shaped to flask-shaped have been found. Some definite proportioned dimensions should be given to the genera to separate this genus from *Lagunculina* and *Proteonina* in their fossil forms.

LAGENAMMINA SPHAERICA Moreman
Plate 42, figure 29

Lagenammina sphaerica MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 51.

Moreman's description.—Test free, small, bottle-shaped, that part of the chamber below the neck almost perfectly spherical, neck about two-fifths the length of the entire test; wall thin, composed of medium sand, surface rough; aperture circular at the end of an elongate neck; color white. Length, 0.65 mm.; diameter 0.38 mm.

Dimensions.—Figured specimen: length, 0.36 mm., width 0.22 mm.

Occurrence.—Osgood limestone, Missouri, locality 4.

Remarks.—Common in Niagaran.

Hypotype.—Walker Museum, no. 48,429.

LAGENAMMINA STILLA Moreman
Plate 42, figures 30, 31

Lagenammina stilla MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 51.

Moreman's description.—Test free, bottle-shaped, neck short, that part of the chamber below the neck more or less ellipsoidal in outline; wall thin, composed of fine sand, surface smooth; aperture circular at the end of a short neck; color white. Length, 0.44 mm.; width, 0.28 mm.

Dimensions.—Length, 0.33 mm., width, 0.26 mm.

Occurrence.—Joliet limestone, Illinois, locality 1001.

Remarks.—The specimen figured is composed of coarse sand grains. There are nine grains to the diameter of the specimen. Common in restricted zones in the Niagaran. Figure 30 may belong to *Proteonina* because of its short neck.

Hypotypes.—Walker Museum, nos. 48,430, 48,431.

LAGENAMMINA BULBOSA Dunn, n. sp.
Plate 42, figures 21, 26

Test free, bulbous, neck typically short; wall thick, composed of medium to coarse sand grains, well cemented; surface rough to smooth; aperture at end of neck.

Dimensions.—Figure 21: length with neck, 0.67 mm.; greatest diameter, 0.52 mm. Figure 26: length with neck, 0.52 mm.; greatest diameter, 0.47 mm.

Occurrence.—Osgood limestone, Illinois, locality 1009 (fig. 21); Brassfield limestone, Illinois, locality 1001 (fig. 26).

Remarks.—This species is put under this genus instead of *Saccammina*. The two genera, however, are so closely related it is almost impossible to make a separation. It is the belief of this writer that a number of these bottle-shaped genera should be grouped under one genus.

Holotype.—Walker Museum, no. 48,432; paratype, 48,433.

LAGENAMMINA URNIFORMIS
Dunn, n. sp.
Plate 43, figure 4

Test free, urnshaped; neck short with the upper part of the chamber somewhat flattened, wall of medium thickness, composed of small sand grains, well cemented; aperture at end of neck.

Dimensions.—Length with neck, 0.43 mm.; greatest diameter, 0.32 mm.

Occurrence.—Osgood limestone, Missouri, locality 1.

Remarks.—This species was also found in the Niagaran of Tennessee.

Holotype.—Walker Museum, no. 48,434.

Genus SHIDELERELLA Dunn, n. gen.

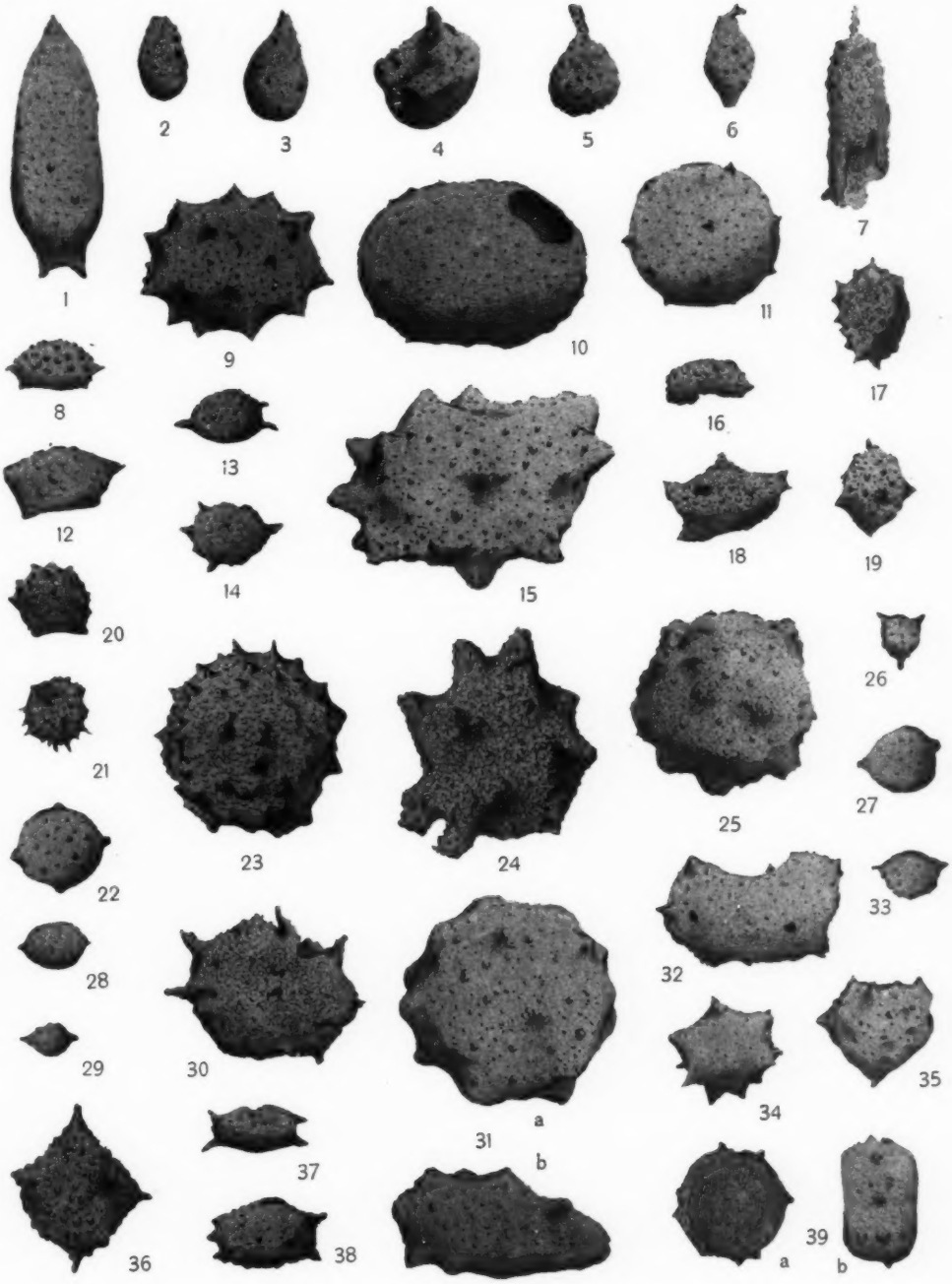
Test free, elongate-fusiform or cylindrical, with upper portion sloping toward a tubular neck; lower end terminating in one or more nipplelike projections that may or may not have been functional as apertures; wall very thin; composed of medium to large sand grains, poorly cemented; apertures at end of neck and sometimes at ends of smaller projections at lower end.

Genotype *Shidelerella biscuspidata* Dunn, n. sp.

Remarks.—Named in honor of Dr. W. H. Shideler, of Miami University.

EXPLANATION OF PLATE 43
All figures ×35

FIG. *1—Shidelerella bicuspida* Dunn, n. gen., n. sp. Locality 1003; Walker Museum, no. 48,435. (p. 329)
2—Proteonina jolietensis Dunn, n. sp. Locality 1001; Walker Museum, no. 48,426. (p. 326)
3—Proteonina acuta Dunn, n. sp. Locality 1002; Walker Museum, no. 48,427. (p. 326)
4—Lagenammina urniformis Dunn, n. sp. Locality 1; Walker Museum, no. 48,434. (p. 328)
5—Lagenammina stilla var. (p. 327)
6—Proteonina? ovata Dunn, n. sp. Locality 1001; Walker Museum, no. 48,428. (p. 327)
7—Shidelerella cylindrica Dunn, n. sp. Locality 2; Museum, no. 48,430. (p. 329)
8—Thurammina slocumi Dunn, n. sp. Locality 1001; Walker Museum, no. 48,470. (p. 333)
9—Thurammina papillata Brady. Locality 1002; Walker Museum, no. 48,505. (p. 330)
10—Thurammina magna Dunn, n. sp. Locality 3; Walker Museum, no. 48,402. (p. 333)
11—Thurammina tubulata Moreman. Locality 1; Walker Museum, no. 48,446. (p. 330)
12—Thurammina slocomi Dunn, n. sp. Locality 1002; Walker Museum, no. 48,471. (p. 333)
13, 14—Thurammina irregularis Moreman, *13*, Locality 1003; Walker Museum, no. 48,441. *14*, Locality 1001; Walker Museum, no. 48,442. (p. 330)
15—Thurammina papillata var. *monticulifera* Ireland. Locality 1002; Walker Museum, no. 48,443. (p. 330)
16—Thurammina phasela Moreman. Locality 1; Walker Museum, no. 48,445. (p. 330)
17—Thurammina triangularis Moreman. Locality 3; Walker Museum, no. 48,448. (p. 331)
18—Thurammina coronata Dunn, n. sp. Locality 1; Walker Museum, no. 48,449. (p. 331)
19—Thurammina? hexactinellida Dunn, n. sp. Locality 1012. (p. 332)
20, 21—Thurammina echinata Dunn, n. sp. *20*, Locality 2; Walker Museum, no. 48,451. *21*, Locality 1001; Walker Museum, no. 48,452. (p. 331)
22—Thurammina quadritubulata Dunn, n. sp. Locality 1; Walker Museum, no. 48,476. (p. 334)
23—Thurammina echinata Dunn, n. sp. Locality 4001; Walker Museum, no. 48,450. (p. 331)
24—Thurammina papillata var. *monticulifera* Ireland. Locality 1009; Walker Museum, no. 48,444. (p. 330)
25—Thurammina quadrata Dunn, n. sp. Locality 1; Walker Museum, no. 48,475. (p. 334)
26—Thurammina trituba Dunn, n. sp. Locality 1; Walker Museum, no. 48,474. (p. 334)
27—Thurammina foerstei Dunn, n. sp. Locality 1001; Walker Museum, no. 48,453. (p. 331)
28, 29—Thurammina parvituba Dunn, n. sp. *28*, Locality 1003; Walker Museum, no. 48,464. *29*, Locality 8; Walker Museum, no. 48,465. (p. 333)
30—Thurammina splendens Dunn, n. sp. Locality 1; Walker Museum, no. 48,472. (p. 334)
31a, b—Thurammina subsphaerica Moreman. Locality 1001; Walker Museum, no. 48,447. (p. 331)
32—Thurammina melleni Dunn, n. sp. Locality 1014; Walker Museum, no. 48,463. (p. 332)
33—Thurammina elliptica Moreman. Locality 7; Walker Museum, no. 48,440. (p. 329)
34—Thurammina limbata Dunn, n. sp. Locality 1; Walker Museum, no. 48,460. (p. 332)
35—Thurammina arcuata Moreman. Locality 1001; Walker Museum, no. 48,439. (p. 329)
36—Thurammina? hexactinellida Dunn, n. sp. Locality 1011; Walker Museum, no. 48,435. (p. 332)
37, 38—Thurammina inflata Dunn, n. sp. Locality 2. *37*, Walker Museum, no. 48,458; *38*, no. 48,457. (p. 332)
39a, b—Thurammina limbata var. *disciformis* Dunn, n. var. Locality 1001; Walker Museum, no. 48,461. (p. 332)



Dunn, Silurian Foraminifera

SHIDELERELLA BICUSPIDATA
Dunn, n. sp.
Plate 43, figure 1

Test free, elongate-fusiform, with upper portion sloping toward a tubular neck and lower portion sloping toward two toothlike projections that may not have had functional apertures throughout the life of the individual; wall thin, composed of medium-sized sand grains, poorly cemented; surface rough; aperture at end of tubular neck, but apertures not apparent at ends of shorter projections.

Dimensions.—Greatest length, 0.89 mm.; greatest diameter, 0.40 mm.

Occurrence.—Osgood limestone, Illinois, locality 1003.

Remarks.—The end of the neck is broken and may have been somewhat longer. Uncommon. The middle point in the illustration is a sand grain.

Holotype.—Walker Museum, no. 48,435.

SHIDELERELLA CYLINDRICA
Dunn, n. sp.
Plate 43, figure 7

Test free, cylindrical, with upper portion terminating in a long tubular neck, and lower portion bearing two or more short tubular projections; wall very thin, composed of rather coarse sand grains, poorly cemented; surface rough; aperture at end of neck, but apertures not apparent at ends of shorter projections.

Dimensions.—Length including projection, 0.72 mm.; greatest diameter, 0.26 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 2.

Remarks.—As the lower part of the test is broken, the exact length and the exact number of terminal projections cannot be determined. A complete specimen of this species was not found, but fragments were common enough to erect this new species.

Holotype.—Walker Museum, no. 48,430.

SHIDELERELLA ELONGATA
Dunn, n. sp.
Plate 42, figures 32, 33

Test free, cylindrical, with upper portion terminating in a long tubular neck and the lower portion sloping into a long neck, which may not have been functional; wall thin, composed of medium sand grains, poorly cemented; surface slightly roughened; aperture at end of upper neck, but not apparent in lower neck.

Dimensions.—Length with tubes, 0.52 mm.; diameter, 0.20 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 2.

Remarks.—Figure 32, though differing in shape, length of lower neck, and character of the surface, may belong to the same species.

Holotype.—Walker Museum, no. 48,437 (fig. 33); paratype 48,438.

Genus THURAMMINA Brady, 1879

Thurammina BRADY, *1879*, Quart. Jour. Micr. Sci., vol. 19, p. 45.
Thurammina, RHUMBLER, *1903*, Arch. Prot., vol. 3, p. 236.
Lituola (part) CARPENTER, *1875*, The Microscope, ed. 5, p. 533.
Thurammina, CUSHMAN, *1928*, Foraminifera, p. 77.

Cushman's description.—Test typically free, usually nearly spherical but in some species compressed, chamber typically single and undivided; wall thin, of fine sand with more or less chitin; apertures several to many at the ends of nipple-like protuberances of the surface, occasionally wanting.

Remarks.—In order to embrace all of the species that are placed in this genus, the above description should include tests of coarse as well as fine sand and those with tubelike as well as nipplelike protuberances.

THURAMMINA ARCUATA Moreman
Plate 43, figure 35

Thurammina arcuata MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 54.

Moreman's description.—Test free, somewhat inflated, arcuate, triangular or polygonal in outline; wall thin, composed of fine sand with much cement, surface smooth; apertures at the end of broad to distinct nipples located along the margin of the test at the corners, two, three or four in number; color white. Measurements, 0.32 by 0.34 and 0.34 by 0.36 mm.

Dimensions.—0.34 by 0.34 mm.

Occurrence.—Joliet limestone, Illinois, locality 1001.

Remarks.—Uncommon.

Hypotype.—Walker Museum, no. 48,439.

THURAMMINA ELLIPTICA Moreman
Plate 43, figure 33

Thurammina elliptica MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 54.

Moreman's description.—Test free, ellipsoidal; wall thin, composed of fine sand well cemented; one aperture on each end at the end of a tube-like projection; color white. Length 0.3 and 0.4 mm.

Dimensions.—Length, including projections, 0.32 mm.; thickness, 0.22 mm.

Occurrence.—Brassfield limestone, Missouri, locality 7.

Remarks.—A distinctive character is the unequal proportions of the upper portion of the test as compared with the lower. If the test is divided in the plane of the tubes the lower portion contains at least two thirds of the volume, the upper portion only one third. A common species in the Brassfield.

Hypotype.—Walker Museum, no. 48,440.

THURAMMINA IRREGULARIS Moreman
Plate 43, figures 13, 14

Thurammina irregularis MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 52.

Moreman's description.—Test free, usually single but sometimes attached in linear series, each independent of the other, chamber subspherical, the location of the apertures giving it an irregular outline; wall thin, composed of fine to medium sand well cemented; apertures few to many situated at the end of nipplelike projections which are variable in size and distribution; color white. Diameter, 0.3 and 0.32 mm.

Dimensions.—Figure 13, a typical specimen; 0.20 by 0.30 mm.

Occurrence.—Osgood limestone, Illinois, locality 1003 (fig. 13); Joliet limestone, Illinois, locality 1001 (fig. 14).

Remarks.—These irregular specimens of the genus *Thurammina* are very common in the Silurian. Some of the specimens will eventually prove to be definite species.

Hypotypes.—Walker Museum, nos. 48,441, 48,442.

THURAMMINA PAPILLATA Brady
Plate 43, figure 9

"Orbuline lituola" CARPENTER, *1875*, The Microscope, 5th ed., p. 553, fig. 273g, h.

Thurammina papillata BRADY, *1879*, Quart. Jour. Micr. Sci., vol. 19, p. 45, pl. 5, figs. 4–8.

Thurammina papillata, CUSHMAN, *1928*, Foraminifera, pl. 4, fig. 16–18 (after type figures).

Thurammina papillata, MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 51.

Moreman's description.—Test free, spherical; wall thin, composed of fine sand with much cement, smoothly finished; apertures many, at the end of nipple-like projections; color white or brownish. Diameter, 0.84 mm.

Dimensions.—Including projections, 0.66 by 0.56 mm.

Occurrence.—Osgood limestone, Illinois, locality 1002.

Remarks.—Common in restricted zones.

Hypotype.—Walker Museum, no. 48,505.

THURAMMINA PAPILLATA var. MONTICULIFERA Ireland
Plate 43, figure 15, 24

Thurammina papillata var. *monticulifera* IRELAND, *1939*, Jour. Paleontology, vol. 13, p. 197.

Ireland's description.—Test free, spherical with a very rough surface due to many large uniformly spaced monticules of medium to large sand grains with strong cement; apertures at the ends of the monticules. Dimensions, 0.68 mm.

Dimensions.—Figure 15, average diameter, 0.77 mm.; figure 24, average diameter, 0.67 mm.

Occurrence.—Osgood limestone, Illinois, localities 1002 (fig. 15) and 1009 (fig. 24).

Remarks.—These specimens differ from Ireland's in the irregular spacing of the "monticules" and the lack of regular spherical outline.

Hypotypes.—Walker Museum, nos. 48,443, 48,444.

THURAMMINA PHASELA Moreman
Plate 43, figure 16

Thurammina phasela MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 34.

Moreman's description.—Test free, bean-shaped; wall thin, composed of fine sand well cemented; apertures numerous at the end of tube-like projections situated at the ends of the test, usually more numerous at one end; color white. Length, 0.32 by 0.24 mm. and 0.4 by 0.24 mm.

Dimensions.—Fig. 16, 0.34 by 0.16 mm.

Occurrence.—Osgood limestone, Missouri, locality 1.

Remarks.—As the number of projections is variable, it is probable that this species will later be subdivided.

Hypotype.—Walker Museum, no. 48,445.

THURAMMINA TUBULATA Moreman
Plate 43, figure 11

Thurammina tubulata MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 52.

Moreman's description.—Test free, spherical; wall thin, composed of very fine sand with much cement, surface smooth; apertures circular and numerous at the end of well formed tube-like projections; color white. Diameter, 0.44 mm.

Dimensions.—Diameter, 0.60 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—Common in the Niagaran.

Hypotype.—Walker Museum, no. 48,446.

THURAMMINA SUBSPHAERICA Moreman
Plate 43, figure 31a, b

Thurammina subsphaerica MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 52.

Moreman's description.—Test free, somewhat ellipsoidal in outline and slightly compressed; wall thin, composed of fine sand with much cement, surface smooth; apertures numerous and circular at the end of broad nipple-like projections, the nipples longer and more numerous around the borders; color brownish. Length, 1.2 mm.; width 1.08 mm.; thickness, 0.6 mm.

Dimensions.—Length, 0.84 mm.; width, 0.82 mm.; thickness, 0.42 mm.

Occurrence.—Joliet limestone, Illinois, locality 1001.

Remarks.—The figured specimen is not quite as large as the one figured by Moreman but compares favorably in all other characters. Common.

Hypotype.—Walker Museum, no. 48,447.

THURAMMINA TRIANGULARIS Moreman
Plate 43, figure 17

Thurammina triangularis MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 54.

Moreman's description.—Test free, three or four sided, the sides being more or less triangular in outline; wall composed of fine sand well cemented; apertures at the end of tube-like projections situated along the somewhat carinate borders; color white. Length 0.4 and 0.4 mm.

Dimensions.—Longest diameter, 0.38 mm.; shortest diameter, 0.33 mm.

Occurrence.—Osgood limestone, Missouri, locality 3.

Remarks.—The question arises whether flattened specimens with triangular outline and with only two sides should be placed in this genus. Uncommon.

Hypotype.—Walker Museum, no. 48,448.

THURAMMINA CORONATA Dunn,
n. sp.
Plate 43, figure 18

Test free, crown-shaped, with one or two tubular projections at either end and more prominent projections extending upward; wall very fragile, composed of large sand grains, poorly cemented, surface rough; apertures at ends of tubes.

Dimensions.—Length with tubes, 0.52 mm.; length without tubes, 0.44 mm.; height with tubes, 0.34 mm.; height without tubes, 0.26 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—May be recognized by its shape, position and number of projections and its fragile nature. Uncommon.

Holotype.—Walker Museum, no. 48,449.

THURAMMINA ECHINATA Dunn,
n. sp.
Plate 43, figure 20, 21, 23

Test free, subspherical, with pointed tubular projections almost completely covering surface; wall thin, composed of medium-sized sand grains, poorly cemented; surface rough; apertures numerous at ends of tubes.

Dimensions.—Greatest diameter with projections: figure 20, 0.26 mm.; figure 21, 0.30 mm.; figure 23, 0.62 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 2 (fig. 20); Joliet limestone, Illinois, locality 1001 (fig. 21); Osgood limestone, Tennessee, locality 4001 (fig. 23).

Holotype.—Walker Museum, no. 48,450; (fig. 23); paratypes, 48,451, 48,452.

THURAMMINA FOERSTEI Dunn,
n. sp.
Plate 43, figure 27

Test free, spherical; wall thick, composed of fine sand grains, well cemented, surface typically smooth, apertures at ends of short rounded projections, one at either end of the test.

Dimensions.—Figure 27: diameter with projection, 0.29 mm.; diameter without projection, 0.24 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001.

Remarks.—This species is named in honor of the late August H. Foerste, Steel High School, Dayton, Ohio. It may be separated from its congeners by its spherical shape, short, rounded projections, and thick wall. Uncommon.

Holotype.—Walker Museum, no. 48,453.

THURAMMINA HEXAGONA Dunn, n. sp.
Plate 44, figure 15

Test free, with a hexagonal outline due to regular flattened portions of the test; wall of medium thickness, composed of rather large sand grains, well cemented; apertures at ends of low nipplelike projections.

Dimensions.—Greatest diameter, 0.51 mm.; shortest diameter, 0.46 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—Common in limited zones.

Holotype.—Walker Museum, no. 48,454.

THURAMMINA? HEXACTINELLIDA Dunn, n. sp.
Plate 43, figures 19, 36

Test free, subspherical; wall usually thick, composed of large sand grains, poorly cemented, surface usually very rough; apertures small (or absent) at ends of six evenly spaced spinelike tubes.

Dimensions.—Fig. 36: longest diameter including spines, 0.57 mm.; shortest diameter including spines, 0.46 mm.; average diameter without spinelike tubes 0.38 mm.

Occurrence.—Osgood limestone, Illinois, locality 1012 (fig. 19); Brassfield limestone, Illinois, locality 1011 (fig. 36).

Remarks.—The test has the appearance of being built upon a hexactinelid sponge spicule, but broken specimens show that the spinelike projections are on the surface and are hollow. On some of the specimens, however, no aperture at the end of the spine is visible. This species is referred to *Thurammina* with a great deal of uncertainty. It is a common species in Illinois in the Edgewood, Kankakee and Osgood limestones.

Holotype.—Walker Museum, no. 48,435 (fig. 36).

THURAMMINA INFLATA Dunn, n. sp.
Plate 43, figures 37, 38

Test free, elongate, and inflated; wall thin, composed of medium sand grains, well cemented, surface fairly smooth; apertures at the ends of tubes—three at each end of test.

Dimensions.—Length with spines, 0.58 mm.; diameter, 0.36 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 2.

Remarks.—The ends of the test are somewhat blunt, and the three tubes are evenly spaced on each end. These characters and the inflated test make this species easily recognized. Figure 37 is very similar in shape, but it has been attached in two places and is somewhat smaller.

Holotype.—Walker Museum, no. 48,457 (fig. 38); paratype, 48,458.

THURAMMINA JUBATA Dunn, n. sp.
Plate 44, figure 17

Test free, shaped like a cup with a covered top; wall thin, composed of medium sand grains, poorly cemented, surface fairly smooth; apertures at ends of six tubes, which are attached to the rim of the cup and extend outward at a sharp angle.

Dimensions.—Width across spines, 0.55 mm.; height of cup, 0.43 mm.

Occurrence.—Joliet limestone, Missouri, locality 1001.

Remarks.—This species is not common, but it has been found in the Niagaran of Missouri and Tennessee.

Holotype.—Walker Museum, no. 48,459.

THURAMMINA LIMBATA Dunn, n. sp.
Plate 43, figure 34

Test free, spherical or subspherical, with a row of prominent nipplelike projections around the periphery; wall thin, of medium to large sand grains, usually well cemented; surface rough; number of projections averages ten; apertures at ends of tubes.

Dimensions.—Diameter with projections, 0.42 mm.; diameter without projections, 0.36 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The size, number, position and shape of projections aid in the determination of this species. Uncommon.

Holotype.—Walker Museum, no. 48,460.

THURAMMINA LIMBATA var. DISCIFORMIS Dunn, n. var.
Plate 43, figures 39a, b

Test free, disk-shaped, the walls compressed until they are almost parallel, with a row of prominent nipplelike projections on the periphery; wall thick, composed of medium to coarse sand grains, well cemented, surface rough; number of tubes on this specimen, 12; apertures at ends of tubes.

Dimensions.—Greater diameter with projections, 0.50 mm.; greater diameter without projections, 0.44 mm.; thickness, 0.30 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001.

Remarks.—May be recognized by its disk-shaped outline.

Holotype.—Walker Museum, no. 48,461.

THURAMMINA MAGNA Dunn, n. sp.
Plate 43, figure 10

Test free, large, subspherical; wall thick, of rather fine sand grains, well cemented; apertures at ends of a few short, pointed tubes.

Dimensions.—Greatest diameter of figured specimen, 0.76 mm.; shortest diameter, 0.60 mm.

Occurrence.—Osgood limestone, Missouri, locality 3.

Remarks.—The hole in the figured specimen is not an aperture.

Holotype.—Walker Museum, no. 48,402.

THURAMMINA MELLENI Dunn, n. sp.
Plate 43, figure 32

Test free, with upper surface depressed to form a cup, and lower surface flattened to form an angular base; wall thin, composed of large sand grains, poorly cemented; surface fairly rough; apertures at ends of tubes, which are situated at the rather blunt ends of the tests, usually about five or six at each end.

Dimensions.—Longest diameter, 0.65 mm.; shortest diameter, 0.39 mm.

Occurrence.—Joliet limestone, Illinois, locality 1014.

Remarks.—This species appears bean-shaped from the side but decidedly angular, almost square, from above.

Holotype.—Walker Museum, no. 48,463.

THURAMMINA PARVITUBA Dunn, n. sp.
Plate 43, figures 28, 29

Test free, usually spherical, but sometimes a little elongate; wall very thin, composed of fine well-sorted sand grains, well cemented, surface smooth; apertures at ends of very slender tubular necks, one at each end of the test.

Dimensions.—Figure 28: length including necks, 0.32 mm.; length not including necks, 0.28 mm.; shortest diameter, 0.24 mm. Figure 29: length including neck, 0.19 mm.; length not including neck, 0.13 mm.; shortest diameter, 0.12 mm.

Occurrence.—Osgood limestone, Illinois, locality 1003 (fig. 28); Osgood limestone, Missouri, locality 8 (fig. 29).

Remarks.—The last specimen is very small in comparison and may not belong to this species. Common in the Osgood.

Holotype.—Walker Museum, no. 48,464 (fig. 28); paratype 48,465.

THURAMMINA? SEMINAFORMIS Dunn, n. sp.
Plate 44, figures 2–5

Test free, seed-shaped, with a single short, nipplelike tube at either end, the portion of test above the plane of the tubes is equal to that below; wall thin, of very fine sand grains, well cemented, surface smooth; apertures at ends of tubes.

Dimensions, including projections.—Figure 2: length, 0.36 mm.; diameter, 0.26 mm. Figure 3: length, 0.53 mm.; diameter, 0.29 mm. Figure 4: length, 0.38 mm.; diameter, 0.24 mm. Figure 5: length, 0.36 mm.; diameter, 0.24 mm.

Occurrence.—Brassfield limestone, Illinois, locality 1001 (fig. 2); Brassfield limestone, Missouri locality 7 (fig. 3).

Remarks.—This common Brassfield species is a good index fossil. It may not belong to the genus *Thurammina*, for its shape suggests the family Allogromiidae.

Holotype.—Walker Museum, no. 48,466 (fig. 3); paratypes, 48,467–48,469.

THURAMMINA SLOCOMI Dunn, n. sp.
Plate 43, figure 8, 12

Test free, ellipsoidal to subquadrangular, the upper surface rounded, the lower flattened; two nipplelike projections at either end, the upper pair extending directly outward at the point of greatest length of the test, and the lower pair extending downward at an angle of 45° from the ends of the flattened base; wall thin, composed of rather large sand grains, poorly cemented, surface rough; apertures at ends of nipplelike projections.

Dimensions.—Figure 8: greatest length including projections, 0.36 mm.; length not including projections, 0.30 mm.; height, 0.22 mm.; distance between lower projections, 0.20 mm. Figure 12: greatest height includ-

ing projections, 0.34 mm.; length not including projections, 0.28 mm.; height, 0.24 mm.; distance between lower projections, 0.18 mm.

Occurrence.—Osgood limestone, Illinois, localities 1001 (fig. 8) and 1002 (fig. 12).

Remarks.—This species is named in honor of the late Arthur W. Slocom of Walker Museum. Common in the Osgood.

Holotype.—Walker Museum, no. 48,470 (fig. 8); paratype, 48,471.

THURAMMINA SPLENDENS Dunn, n. sp.
Plate 43, figure 30

Test free, subspherical to ovate; wall very thin and fragile, composed of sand grains of mixed sizes, poorly cemented, surface rough; apertures numerous, at the ends of long tubular necks, which are irregularly spaced around the periphery.

Dimensions.—Figure 30: length including necks, 0.70 mm.; length not including necks, 0.54 mm.; diameter not including necks, 0.40 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The long slender necks and the fragile test are identifying characters.

THURAMMINA STELLIFORMIS Dunn, n. sp.
Plate 44, figure 9

Test free, with seven prominent nipplelike protuberances equally spaced on the surface and giving the test a five-pointed star-shaped outline; wall thin, composed of fine transparent sand grains, well cemented, surface smooth; apertures at ends of protuberances.

Dimensions.—Greatest diameter including projections, 0.44 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The transparency of the test is one of the identifying characters. The specimen does not cast a shadow, as the light passes through it. A rather common species in the Niagaran of Missouri but uncommon in Illinois.

Holotype.—Walker Museum, no. 48,473.

THURAMMINA TRIBUTA Dunn, n. sp.
Plate 43, figure 26

Test free, triangular, depressed, with a tubelike projection at each corner of the triangle; wall thin, composed of fine sand, well cemented, surface rough; apertures at ends of tubes.

Dimensions.—Diameter from the end of one projection to the opposite side, 0.20 mm.

Occurrence.—Osgood limestone, Missouri, locality 1.

Remarks.—This species may be confused with *T. triangularis*, which, however, is pyramidal. Not common.

Holotype.—Walker Museum, no. 48,474.

THURAMMINA QUADRATA Dunn, n. sp.
Plate 43, figure 25.

Test free, subspherical, with a number of low, broad nipplelike projections, which give it a quadrate outline; wall thin, composed of large sand grains, poorly cemented, surface rough; apertures at ends of projections.

Dimensions.—Diameter, 0.54 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—May be recognized by its angular outline and by its fragile appearance. Uncommon.

Holotype.—Walker Museum, no. 48,475.

THURAMMINA QUADRITUBULATA
Dunn, n. sp.
Plate 43, figure 22

Test free, spherical, with four blunt tubular necks arranged in opposite pairs, the horizontal plane of one pair cutting the vertical plane of the other at right angles. Viewed from above, however, the four tubes do not lie in vertical planes through the center of the sphere but are offset on opposite sides of perpendicular vertical central planes. Wall thin, composed of medium-sized sand grains, well cemented, surface rough; apertures at ends of tubular necks.

Dimensions.—Diameter with projections, 0.42 mm.; diameter without projections, 0.34 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—Common in restricted zones in the Bainbridge.

Holotype.—Walker Museum, no. 48,476.

Genus CRONEISELLA Dunn, n. gen.

Test free, cylindrical, constricted in the central portion and sometimes slightly bent,

with both ends sloping toward pointed necks; wall thin, composed of medium to fine sand grains, well cemented, surface rough; apertures at ends of necks.

Genotype, *Croneisella typa*.

Remarks.—If species with more than one functional neck at either end are found this discription will need to be revised to include that character. This genus is named in honor of Dr. Carey Croneis, University of Chicago.

CRONEISELLA TYPA Dunn,
n. gen., n. sp.
Plate 44, figures 10, 11

Test free, cylindrical, constricted in the central portion and sometimes slightly bent, with both ends sloping toward pointed necks; wall thin, composed of medium to fine sand grains, well cemented, surface rough; apertures at ends of necks.

Dimensions.—Figure 10: length including necks, 0.49 mm.; length not including necks, 0.45 mm.; diameter, 0.13 mm. Figure 11: length including necks, 0.58 mm.; length not including necks, 0.50 mm.; diameter, 0.23 mm.

Occurrence.—Osgood limestone, Missouri, locality 1 (fig. 10); Brassfield limestone, Illinois, locality 1011 (fig 11).

Remarks.—In both of the figured specimens the neck on one end seems to be larger and longer than the one on the other end. Uncommon.

Holotype.—Walker Museum, no. 48,477 (fig. 11); paratype, 48,478.

Genus AMMOSPHAEROIDES Cushman, 1910

Ammosphaeroides CUSHMAN, *1910*, U. S. Nat. Mus. Bull. 71, pt. 1, p. 51.
Ammosphaeroides, CUSHMAN, *1933*, Foraminifera, 2d ed., p. 76.

Cushman's description—Test free, consisting of an elongate or subspherical chamber; wall finely arenaceous with a large proportion of reddish-brown cement; aperture typically double, at the end of short tubular portions of the test.—Recent, Sea of Okhotsk, 82 fathoms.

Genotype.—Ammosphaeroides distoma Cushman.

Remarks.—By the word "double" Cushman evidently means having two apertures, not one double aperture.

AMMOSPHAEROIDES SCOTTI
Dunn, n. sp.
Plate 44, figure 14

Test free, consisting of an elongate chamber slightly constricted in the middle to give the appearance of two chambers; wall of fine sand grains, poorly cemented, surface slightly roughened, apertures at ends of two short tubelike projections, which extend outward at an angle of about 45°, one from each of the swollen portions of the test.

Dimensions.—Length, 0.40 mm.; diameter, 0.24 mm.

Occurrence.—Osgood limestone, Missouri, locality 4.

Remarks.—The position of the tubular projections and the constrictions in the middle of the test give this species the appearance of being two-celled with a separate aperture for each cell. It is impossible to tell whether there is a wall between these two divisions. Also found in the Osgood of Illinois. This species is named in honor of Dr. Harold W. Scott, University of Illinois.

Holotype.—Walker Museum, no, 48,479.

Genus GASTROAMMINA Dunn, n. gen.

Test free, stomach-shaped, large, composed of a proloculum and strongly inflated second chamber. The proloculum has three rounded regularly spaced, nipplelike projections, which do not have apertures. Wall thin, composed of rather large sand grains, poorly cemented, surface rough; aperture at the end of a broad tubular portion of the test.

Genotype, *Gastroammina williamsae* Dunn.

Remarks.—Numerous broken specimens were found with this stomach-shaped character. It is believed that a number of species will be found to belong to this genus.

GASTROAMMINA WILLIAMSAE Dunn,
n. gen., n. sp.
Plate 44, figure 35

Test free, composed of a proloculum and strongly inflated second chamber. The proloculum has three rounded, regularly spaced, nipplelike projections, which do not have apertures. The complete test is stomach-shaped and larger than the average test of arenaceous foraminifera. Wall thin, com-

posed of rather large sand grains, poorly cemented, surface rough; aperture at the end of a broad, tubular portion of the test.

Dimensions.—Height of proloculum, 0.40 mm.; width of proloculum, 0.64 mm.; height of second chamber, 0.82 mm.; width of second chamber, 0.60 mm.; width of second chamber plus proloculum, 0.88 mm.

Occurrence.—Osgood limestone, Missouri, locality 8.

Remarks.—As the end of the neck of the figured specimen is broken, the true appearance of the neck and aperture cannot be given. Several fragments of other specimens were found, but because of the large size and fragility of the wall it was very difficult to restore, and the above description was based entirely upon the figured specimen. Rare. This species is named in honor of my wife, Florence Williams Dunn.

Holotype.—Walker Museum, no. 48,480.

Subfamily WEBBINELLINAE Cushman

Test attached; wall of agglutinated foreign material.

Genus COLONAMMINA Moreman, 1930

Colonammina MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 55.

Moreman's description.—Test attached, planoconvex, circular or elliptical in outline, attached surface surrounded by a more or less flattened border; wall thin, composed of fine sand well cemented; aperture single on the convex surface.

Remarks.—This description should include Foraminifera with two and possibly more apertures.

COLONAMMINA BITUBA Dunn, n. sp
Plate 44, figure 16

Test attached, planoconvex, circular in outline, surface surrounded by a more or less flattened border; wall thin, composed of

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EXPLANATION OF PLATE 44

All figures ×27

FIG. *1*—*Raibosammina aspera* Moreman. Locality 1001; Walker Museum, no. 48,423. (p. 325)
2–5—*Thurammina? seminaformis* Dunn, n. sp. Locality 1001; Walker Museum. *2*, No. 48,467; *3*, no. 48,466; *4*, no. 48,468; *5*, no. 48,469. (p. 333)
6—*Hyperammina sublaevigata* Dunn, n. sp. Locality 1; Walker Museum, no. 48,484. (p. 337)
7—*Hyperammina hastula* Moreman. Locality 1001; Walker Museum, no. 48,485. (p. 337)
8—*Tholosina? dubia* Dunn, n. sp. (p. 337)
9—*Thurammina stelliformis* Dunn, n. sp. Locality 1; Walker Museum, no. 48,473. (p. 334)
10, 11—*Croneisella typa* Dunn, n. gen., n. sp. *10*, Locality 1; Walker Museum, no. 48,478. *11*, Locality 1011; Walker Museum, no. 48,477. (p. 335)
12, 13—*Tholosina? dubia* Dunn, n. sp. Locality 1; Walker Museum. *12*, No. 48,482; *13*, no. 48,483. (p. 337)
14—*Ammosphaeroides scotti* Dunn, n. sp. Locality 4; Walker Museum, no. 48,479. (p. 335)
15—*Thurammina hexagona* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,454. (p. 332)
16—*Colonammina bituba* Dunn, n. sp. Locality 1; Walker Museum, no. 48,481. (p. 336)
17—*Thurammina jubata* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,459. (p. 332)
18—*Ammodiscus furca* Moreman. Locality 3; Walker Museum, no. 48,488. (p. 338)
19–21—*Tolypammina tortuosa* Dunn, n. sp. Locality 7. Walker Museum. *19*, No. 48,502; *20*, no. 48,501; *21*, no. 48,503. (p. 341)
22—*Turritellella osgoodensis* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,500. (p. 341)
23—*Ammodiscus exsertus* Cushman. Locality 3; Walker Museum, no. 48,487. (p. 338)
24—*Ammodiscus brevitubus* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,491. (p. 339)
25—*Ammodiscus furca* Moreman. Locality 1002; Walker Museum, no. 48,489. (p. 338)
26—*Ammodiscus incertus* (d'Orbigny). Locality 3; Walker Museum, no. 48,486. (p. 338)
27—*Ammodiscus constrictus* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,490. (p. 339)
28—*Ammodiscus minutus* Dunn, n. sp. Locality 8; Walker Museum, no. 48,492. (p. 339)
29—*Lituotuba salinensis* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,495. (p. 340)
30—*Turritellella fisheri* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,498. (p. 340)
31—*Turritellella workmani* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,499. (p. 341)
32—*Tolypammina tortuosa* Dunn, n. sp. Section through center of specimen. Locality 7; Walker Museum, no. 48,504. (p. 341)
33—*Lituotuba exserta* Moreman. Locality 1; Walker Museum, no. 48,493. (p. 339)
34—*Lituotuba? furca* Dunn, n. sp. Locality 1001; Walker Museum, no. 48,496. (p. 340)
35—*Gastroammina williamsae* Dunn, n. gen., n. sp. Locality 8; Walker Museum, no. 48,480. (p. 335)
36—*Lituotuba elongata* Dunn, n. sp. Locality 7; Walker Museum, no. 48,497. (p. 340)
37—*Lituotuba exserta* Moreman. Locality 1; Walker Museum, no. 48,494. (p. 339)

Dunn, Silurian Foraminifera

fine sand grains, well cemented, surface rough; apertures on the ends of two nipple-like projections on the convex surface.

Dimensions.—Width, 0.50 mm.; height, 0.24 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—This species differs from *C. verruca* Moreman, the genotype, in having two apertures. Common in the Bainbridge.

Holotype.—Walker Museum, no. 48,481.

Genus THOLOSINA Rhumbler, 1895

Tholosina RHUMBLER, *1845*, Kongl. Gesell. Wiss. Göttingen Nachr., p. 82.
Placopsilina (part) BRADY, *1879*, Quart. Jour. Micr. Sci., vol. 19, p. 51.
Pseudoplacopsilina ELMER and FICKERT, *1899*, Zeitschr. Wiss. Zool., vol. 65, p. 672.
Tholosina, CUSHMAN, *1933*, Foraminifera, p. 78.

Cushman's description.—Test attached, a hemispherical chamber, undivided; wall of sand grains with a large proportion of calcareous cement; apertures small, circular, protuberant or irregular, just above the base of the test—Silurian, Recent.

THOLOSINA? DUBIA Dunn, n. sp.
Plate 44, figures 12, 13

Test attached at one or two points, apparently to slender objects, subspherical in shape; wall thick, composed of medium sand grains, well cemented, surface rough; aperture at the end tube, which is close to point of attachment.

Dimensions.—Figure 12: diameter, 0.34 mm.; figure 13: diameter, 0.40 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—This species is similar to other members of the genus with the exception of its attached surface. The general shape of other species is hemispherical, with a broad area of attachment, whereas this species has one or two narrow, notch-shaped areas of attachment and is almost spherical in general shape. Common. The specimen (fig. 8) may not belong to this genus, for it has no tube. However, the mode of attachment is the same as in figures 10 and 11.

Holotype.—Walker Museum, no. 48,482; paratype, 48,483.

Family HYPERAMMINIDAE Eimer and Fickert, 1899

Test free or attached, consisting of a globular proloculum and a more or less elongate but not close-coiled, sometimes branching portion, not divided into chambers; wall of various agglutinated materials with a basal layer of chitin.

Subfamily HYPERAMMINIDAE Cushman

Test free, simple.

Genus HYPERAMMINA Brady, 1878

Hyperammina BRADY, *1878*, Annals and Mag. Nat. History, ser. 5, vol. 1, p. 433.
Rhabdopleura (?) DAWSON, *1871*, *idem*, ser. 4, vol. 7, p. 86.
Bactrammina EIMER and FICKERT, *1899*, Zeitschr. Wiss. Zool., vol. 65, p. 673.
Hyperammina, CUSHMAN, *1928*, Foraminifera, p. 83.

Cushman's description—Test free, elongate, consisting of a proloculum and long undivided tubular second chamber; wall of sand grains, often with sponge spicules, amount of cement varying in different species, interior with chitinous lining and smoothly finished; aperture formed by the open end of the tube.

HYPERAMMINA SUBLAEVIGATA Dunn, n. sp.
Plate 44, figure 6

Test free, elongate, curved, consisting of a proloculum, and a long undivided second chamber; proloculum pointed; wall of medium to fine sand grains, usually well cemented but sometimes very poorly cemented. Aperture at open end of tube.

Dimensions—Length, 0.01 mm.; diameter at open end, 0.10 mm.; diameter near proloculum, 0.16 mm.; diameter of proloculum, 0.09 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—This genus is difficult to distinguish from *Bathysiphon* when the proloculum is lost. Common in the Niagaran.

Holotype.—Walker Museum, no. 48,484.

HYPERAMMINA HASTULA Moreman
Plate 44, figure 7

Hyperammina hastula MOREMAN, *1933*, Jour. Paleontology, vol. 7, p. 396.

Moreman's description.—Test free, elongate, medium size, consisting of a small spherical proloculum and a long tubular second chamber; wall thin, composed of small to medium sand grains set together with a small amount of cement, exterior rough; large aperture formed by the open end of the tube.

The proloculum of *Hyperammina hastula* is smaller in proportion to the length of the tube and more distinctly formed than that of *Hyper-*

ammina elongata H. B. Brady. The wall of the test is thinner, being composed of rather fine sand grains, and the canal of the second chamber is relatively greater in diameter.

Dimensions.—Length of specimen with proloculum, 0.68 mm.; diameter of proloculum, 0.12 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—My specimens seemed to have a longer, more slender proloculum than the one figured by Moreman. Common in the Osgood.

Hypotype.—Walker Museum, no. 48,485.

Family AMMODISCIDAE Rhumbler, 1895

Test composed of a globular proloculum and long undivided tubular second chamber, usually close-coiled, at least in the young, planispiral, conical spiral or irregularly winding; wall of fine arenaceous material with much cement, usually yellowish or reddish-brown; aperture formed by the open end of the tubular chamber.

Subfamily AMMODISCINAE Cushman

Test free.

Genus AMMODISCUS Reuss, 1861

Ammodiscus REUSS, *1861*, Akad. Wiss. Wien, Sitzungsber., vol. 44, p. 365.
Operculina (part) D'ORBIGNY, *1839*, in De la Sagra, Histoire phys., polit., et nat. de Cuba, p. 49.
Orbis STRICKLAND, *1848*, Geol. Soc. London Quart. Jour., vol. 2, p. 30, (not *Orbis* Philipps).
Spirillina WILLIAMSON, *1858*, Rec. Foram. Great Britain, p. 93 (not *Spirillina* Ehrenberg, 1841).
Trochammina (part) of authors.
Cornuspira (part) of authors.
Involutina (part), TERQUEM, *1862*, Acad. Imp. Metz Mém., 1860–61, p. 450.
Ammodiscus, CUSHMAN, *1928*, Foraminifera, p. 99.

Cushman's description.—Test free, planispiral, with a proloculum and long tubular undivided second chamber, coiled regularly in one plane; wall finely arenaceous with a large proportion of yellowish- or reddish-brown cement, surface smooth; aperture formed by the open end of the chamber.

Remarks.—The specimens from the Silurian are commonly white.

AMMODISCUS INCERTUS (d'Orbigny)
Plate 44, figure 26

Operculina incerta D'ORBIGNY, *1839*, in De la Sagra, Histoire phys., polit., et Nat. Cuba, p. 49, pl. 6, fig. 16, 17; Spanish Edit., 1849, p. 71, pl. 6, figs. 16, 17.
Ammodiscus incertus, BRADY, *1884*, *Challenger* Rept., Zoology, vol. 9, p. 330, pl. 38, figs. 1–3.
Ammodiscus incertus, CUSHMAN, *1928*, pl. 9, figs. 1–4 (after type figures).
Ammodiscus incertus, MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 58.

Moreman's description.—Test free, composed of an ovoid proloculum and long undivided second chamber, coiled regularly in one plane; wall finely arenaceous with much cement, surface smooth; aperture at the end of the tube, color white. Diameter, 0.42 mm.

Dimensions.—Diameters of figured specimens, 0.34 and 0.32 mm.

Occurrence.—Osgood limestone, Missouri, locality 3.

Remarks.—Very common in the Niagaran.

Hypotype.—Walker Museum, no. 48,486.

AMMODISCUS EXSERTUS Cushman
Plate 44, figure 23

Ammodiscus exsertus CUSHMAN, *1910*, U. S. Nat. Mus. Bull. 71, pt. 1, p. 75, figs. 97a, b (in text); *1921*, *idem*, Bull. 100, vol. 4, p. 64, pl. 5, fig. 4.
Ammodiscus exsertus, MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 58.

Moreman's description.—Test free, consisting of an ovoid proloculum and tubular second chamber close coiled for several revolutions, then uncoiling, but in the same plane, uncoiled portion straight, of varying length and usually turned at right angles to the direction of coiling; wall composed of fine sand with much cement, surface smooth; aperture at the end of the uncoiled portion, circular and slightly constricted; color white. Diameter, 0.42 mm.

Dimensions.—Specimen, 0.49 by 0.38 mm.

Occurrence.—Osgood limestone, Missouri, locality 3.

Remarks.—Very common in the Niagaran.

Hypotype.—Walker Museum, no. 48,487.

AMMODISCUS FURCA Moreman
Plate 44, figures 18, 25

Ammodiscus? furca MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 59.

Moreman's description.—Test free, consisting of two chambers, a proloculum and second tubular chamber planispirally coiled, the second chamber at first a single tube but in the last coil dividing into two branches which grow out as straight tubes at once or continue to coil for part of a revolution before straightening out; in some the outer branch again divided into two, thus forming three tubes with apertures; wall composed of fine sand with much cement; two or three circular apertures at the ends of the branched second chamber, slightly constricted; color white. Diameter, 0.32 mm. and 0.48 mm.

Dimensions.—Figure 18, 0.44 by 0.34 mm.; figure 25, 0.57 by 0.46 mm.

Occurrence.—Osgood limestone, Missouri, locality 3 (fig. 18); Osgood limestone, Illinois, locality 1002 (fig. 25).

Remarks.—Uncommon.

Hypotypes.—Walker Museum, nos. 48,488 and 48,489.

AMMODISCUS CONSTRICTUS Dunn, n. sp.
Plate 44, figure 27

Test free, consisting of an ovoid proloculum and tubular second chamber, close coiled for several revolutions, then uncoiling in the same plane at an angle of 45°; uncoiled portion constricted close to end; wall composed of fine sand grains, well cemented; aperture at end of uncoiled portion, circular and unconstricted.

Dimensions.—0.28 by 0.24 mm.

Occurrence.—Joliet limestone, Illinois, locality 1001.

Remarks.—This species may be recognized by the constriction back of the aperture and by the 45° angle of the uncoiled portion. Uncommon.

Holotype.—Walker Museum, no. 48,490.

AMMODISCUS BREVITUBUS Dunn, n. sp.
Plate 44, figure 24

Test free, consisting of an ovoid proloculum and a swollen, tubular second chamber, coiled for about two revolutions in one plane, then uncoiling but in the same plane; uncoiled portion straight and turned at right angles to the direction of coiling; wall thick, composed of fine sand grains with much cement, surface smooth; aperture at end of uncoiled portion, circular and slightly constricted.

Dimensions.—Diameter, 0.34 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—This species may be separated from its congeners by the reduced number of coils and by the inflated condition throughout the entire length. It is not the megalospheric form of *A. exsertus*. Uncommon.

Holotype.—Walker Museum, no. 48,491.

AMMODISCUS MINUTUS Dunn, n. sp.
Plate 44, figure 28

Test free, small, composed of an ovoid proloculum and undivided tubular second chamber, coiling regularly in one plane for two or three revolutions; wall thin, composed of fine sand grains, rather poorly cemented, surface smooth; aperture at end of tube.

Dimensions.—Average diameter, 0.22 mm.

Occurrence.—Osgood limestone, Missouri, locality 8.

Remarks.—Since there are no known intermediate forms between this species and *A. incertus*, this species probably does not represent the young of that larger species. A common species in the Osgood but found only rarely at higher levels in the Niagaran. In Missouri, especially, it can be used as an Osgood index fossil.

Holotype.—Walker Museum, no. 48,492.

Genus LITUOTUBA Rhumbler, 1895

Lituotuba RHUMBLER, *1895*, Kongl. Gesell. Wiss. Göttingen Nachr., 1895, p. 83.
Trochammina (part) of authors.
Lituotuba, CUSHMAN, *1928*, Foraminifera, p. 102.

Cushman's description.—Test composed of a proloculum and elongate undivided tubular second chamber, the early portion close coiled in various planes, the later portion uncoiled; wall arenaceous with much cement; aperture formed by the open end of the tubular chamber.

Remarks.—Possibly this genus can be subdivided on the basis of direction of coiling. Although the majority of specimens are coiled to the left, some are coiled to the right.

LITUOTUBA EXSERTA Moreman
Plate 44, figures 33, 37

Lituotuba exserta MOREMAN, *1930*, Jour. Paleontology, vol. 4, p. 59.

Moreman's description.—Test free, consisting of a proloculum and tubular second chamber winding about its earlier coils in various planes, later portion uncoiling and extending as a straight tube about at right angles to the direction of coiling of the last convolution; wall of fine sand with much cement; aperture circular at the end of the straight portion, slightly constricted; color white. Diameter, 0.34 and 0.48 mm.

Dimensions.—Diameter (fig. 33), 0.35 mm.; (fig. 37), 0.36 mm.

Occurrence.—Bainbridge limestone, Missouri, locality 1.

Remarks.—The specimens here described have fewer coils than those figured by Moreman. The diameter of the specimens seem to be the same, but the diameter of the tubes

in the Missouri and Illinois specimens is greater. This is one of the most common species of foraminifera in the Niagaran of Illinois and Missouri.

Hypotypes.—Walker Museum, nos. 48,473, 48,494.

LITUOTUBA SALINENSIS Dunn, n. sp.
Plate 44, figure 29

Test free, small, consisting of a proloculum and tubular second chamber, making only one or two convolutions, which are not in one plane, and then uncoiling and extending as a straight tube about at right angles to the direction of coiling of the last convolution; wall thick, composed of fine sand, well cemented, surface smooth; aperture at end of uncoiled portion, slightly constricted.

Dimensions.—Diameter plus uncoiled tube, 0.24 mm., diameter without neck, 0.18 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—This is a distinct marker of the Osgood. It is not the megalospheric form of another species.

Holotype.—Walker Museum, no. 48,495.

LITUOTUBA? FURCA Dunn, n. sp.
Plate 44, figure 34

Test free, consisting of a proloculum and tubular second chamber, winding about its earlier coils in various planes, later uncoiling and dividing into two tubes, which extend outward from the coiled portion at right angles to each other; wall thick, composed of fine sand grains, well cemented, surface smooth; apertures at ends of uncoiled portions, somewhat constricted.

Dimensions.—Diameter plus uncoiled tubes, 0.36 and 0.26 mm.

Occurrence.—Joliet limestone, Illinois, locality 1001.

Remarks.—This species bears the same relationship to *L. exserta* as *Ammodiscus? furca* does to *A. exsertus*. It resembles *L. exserta* in every character with the exception of the extra tube. It may be possible that an injury had something to do with this tube division, since both *Ammodiscus* and *Lituotuba* have acquired the same character. Further study is needed to determine the worth of this character, as is indicated by the species named "*furca*."

Holotype.—Walker Museum, no. 48,496.

LITUOTUBA ELONGATA Dunn, n. sp.
Plate 44, figure 36

Test free, consisting of a proloculum and tubular second chamber winding about its earlier coils in various planes, later portion coiling and extending as a straight or slightly curved tube at right angles to the direction of coiling of the last convolution, the length of the uncoiled portion being almost equal to the greatest diameter of the test; wall of fine sand grains, well cemented, surface smooth; aperture at the end of the uncoiled portion, slightly constricted.

Dimensions.—Greatest diameter, 0.26 mm., length of uncoiled portion, 0.22 mm.

Occurrence.—Osgood limestone, Missouri, locality 7.

Remarks.—The extreme length of the uncoiled portion separates the species from its congeners. The fact that some specimens coil to the left while others coil to the right may cause the separation of this species into two varieties.

Holotype.—Walker Museum, no. 48,497.

Genus TURRITELLELLA Rhumbler, 1903

Turritellella RHUMBLER, *1903*, Archiv. Prot., vol. 3, p. 283.
Trochammina (part) SIDDALL, *1878*.
Ammodiscus (part) of authors.
Turritellopsis RHUMBLER, *1895* (not G. O. Sars, 1878).
Turritellella, CUSHMAN, *1933*, Foraminifera, 2d ed., p. 90.

Genotype, *Trochammina shoneana* Siddall.

Cushman's description.—Test free, with a proloculum and long, tubular, undivided, second chamber, coiled in an elongate close spiral; wall finely arenaceous with much cement; aperture formed by the open end of the tubular chamber. —Pennsylvanian to Recent.

TURRITELLELLA FISHERI Dunn, n. sp.
Plate 44, figure 30

Test free, consisting of a small subspherical proloculum and a long undivided tubular second chamber, coiled in an elongate spiral, which is closely coiled and small at first but later more open and larger, especially in the middle of the specimen; wall thick, composed of medium to fine sand grains, well

cemented, surface commonly rough; aperture round, at end of tubular chamber.

Dimensions.—Length, 0.67 mm.; greatest diameter, 0.15 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—This form is slightly bent. It is common in the Osgood of Illinois, Indiana, Missouri, Kentucky and Tennessee. It is rarely found above the Osgood and never below it.

Holotype.—Walker Museum, no. 48,498.

TURRITELLELLA WORKMANI Dunn, n. sp.
Plate 44, figure 31

Test free, consisting of a small subspherical proloculum and a long undivided tubular second chamber, coiled in an elongate spiral, closely coiled for the entire length of the test and with coils of the same size; wall thin, composed of small sand grains well cemented, surface smooth; aperture round, at end of tubular chamber.

Dimensions.—Length, 0.35 mm.; greatest diameter, 0.07 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—The small size and parallel sides will serve to identify this species. It is very common in the Osgood. It has never been found above or below this limestone.

Holotype.—Walker Museum, no. 48,499.

TURRITELLELLA OSGOODENSIS Dunn, n. sp.
Plate 44, figure 22

Test free, consisting of a small subspherical proloculum and a long spiral, with coils large and all of the same size; wall thick, composed of rather large sand grains well cemented, surface usually rough; aperture round, at end of tubular chamber.

Dimensions.—Length of illustrated portion, 0.50 mm.; diameter, 0.15 mm.

Occurrence.—Osgood limestone, Illinois, locality 1001.

Remarks.—The large size, open coiling, and coils of equal size are identifying characters. It is not as common as *T. fisheri* and *T. workmani*, but whenever found it serves as a good Osgood index fossil. A complete specimen is not figured.

Holotype.—Walker Museum, no. 48,500.

Subfamily TOLYPAMMININAE

Test attached.

Genus TOLYPAMMINA Rhumbler, 1895

Tolypammina RHUMBLER, *1895*, K. Gesell. Wiss. Göttingen, Nachr., p. 83.
Hyperammina (part) BRADY, *1879*.
Serpulella and *Ammonema* EIMER and FICKERT, *1899*.
Girvanella (part) of authors (not of Nicholson and Etheridge, 1878).
Tolypammina, CUSHMAN, *1933*, 2d ed., p. 93.

Genotype *Hyperammina vagans* H. B. Brady.

Cushman's description.—Test attached, with proloculum and long, tubular, undivided, second chamber, earliest portion sometimes coiled, later irregular; wall arenaceous with much cement; aperture at the end of the tube.—Pennsylvanian to Recent.

If the attachment is to a small object the test may completely envelop it, and appear to be free.

TOLYPAMMINA TORTUOSA Dunn, n. sp.
Plate 44, figures 19–21, 32

Test, in the young stages at least, attached, but in some cases becoming free, consisting of a spherical proloculum and long tubular second chamber, usually unbranched, the earliest portion commonly coiled, the later portion winding about in an irregular manner, in most cases either inside or around some foreign object; wall thin, composed of fine sand grains rather well cemented, surface somewhat rough; aperture circular, at the end of the tube.

Dimensions.—Average diameter of tube, 0.15 mm.

Occurrence.—Brassfield limestone, Missouri, locality 7.

Remarks.—All figured specimens are from one locality and from the upper seventeen feet of the section. Numerous individuals were found, but no two specimens are exactly alike. In some instances the animal is coiled inside of a hollow object, such as a crinoid stem (see pl. 3, fig. 20) or around some other common object. In some cases it is coiled about an earlier, straight portion of its own test.

It is possible that some subdivision may be made of this species. A number of possible variations are here figured.

Holotype.—Walker Museum, no. 48,501 (fig. 20); paratype 48,502–48,504.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 3, PP. 343–350, PLS. 45–49, MAY 1942

UPPER DEVONIAN BRYOZOA

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ABSTRACT—A description of the little-studied Upper Devonian Bryozoa is the purpose of this paper. One new genus, *Hyalotoechus*, and 14 new species are described. These represent the best material now available for study of a large collection of poorly preserved specimens. Relationships of the fauna appear to be with Middle Devonian rather than Lower Mississippian species.

INTRODUCTION

UPPER DEVONIAN Bryozoa have been little studied. Descriptions of species have appeared in but three papers (Hall and Whitfield, 1873; Fenton and Fenton, 1924; and Bassler, 1939). In comparison, Middle Devonian and Lower Mississippian bryozoans are well known. The present paper is an attempt to add information to the history of the bryozoa recorded in Upper Devonian rocks. Soon after the problem was started it was discovered that lack of described material was not due to scarcity of material but to the method of preservation of specimens, because most of the specimens found were preserved as impressions in shales and sandstones. Detailed information concerning the specimens therefore was not available. The small number of specimens described in this paper represent a careful selection of specimens from a large collection. A number of undoubted new species have not been described due to lack of sufficiently well preserved material.

ACKNOWLEDGMENTS

A grant from the Penrose Bequest of the Geological Society of American made possible the collection of many Upper Devonian specimens. Other specimens have generously been loaned for study by Drs. R. S. Bassler and G. A. Cooper of the United States National Museum, E. R. Eller of the Carnegie Museum, and A. K. Miller of the University of Iowa. Dr. Bradford Willard spent several days in the field with the author in 1936. Dr. G. H. Chadwick has furnished both specimens and information concerning localities. Miss Helen Duncan of the University of Cincinnati has inspected many specimens and has very generously given valued information concerning the taxonomy and relationships of most species that were thin-sectioned.

The writer is deeply indebted to each of these people and institutions and wishes to extend to them his appreciation and thanks.

OCCURRENCE AND RELATIONSHIPS OF SPECIMENS

Almost without exception the specimens found in the Upper Devonian rocks of eastern United States occur either as impressions in shales and sandstones or as recrystallized specimens embedded in limy sandstones. To enable study to be made of these fossils it is necessary that details of external and internal structure be observed. As many of the impressions studied were in coarse-grained sediments, only generic or ordinal identification of them was possible. This is particularly true of localities in Pennsylvania and New York. The specimens that occurred in shales and fine-grained sandstones were studied by means of photographs that reversed the images of the impressions and made the photographic prints appear as actual specimens. The method of photographing such impressions was developed during the course of this study and has been described recently (McNair, 1941, p. 91). Photographs of impressions are shown on Plates 45–47. Stony bryozoa embedded in sandstones were thin-sectioned in the usual manner. The method of occurrence and preservation of the specimens has limited to a large degree the number of specimens that could be described, and further work will undoubtedly disclose many additional species.

The Cryptostomatous bryozoa studied show much greater relationship to Middle Devonian than to Mississippian species. This is also true of the Trepostomata, which

show strong affinities to species described by Duncan in her work on Traverse trepostomatous Bryozoa (1939, pp. 171–270). A discussion of the relationships of particular species is given in the descriptions of species in later pages of this report.

SYSTEMATIC DESCRIPTIONS

Phylum BRYOZOA Ehrenberg
Class ECTOPROCTA Nitsche
Order CRYPTOSTOMATA Vine
Family FENESTRELLINIDAE Bassler
Genus FENESTRELLINA d'Orbigny

FENESTRELLINA COOPERI McNair, n. sp.
Plate 45, figures 1–3, 7; plate 46, figure 2

Zoarium a flabellate expansion.

Obverse: Branches angular; approximately parallel; average width 0.20 mm.; seven in space of 3 mm. Dissepiments slender, rounded; slightly depressed below plane of branches; 5 in space of 3 mm. Fenestrules elliptical, regular, never inflecting apertures; length 0.50 mm.; width 0.24 mm. Apertures small, circular; average diameter 0.09 mm.; those on sides of fenestrules open laterally, those on dissepiments directly upward; 13 in space of 5 mm.; separated by distances approximately three times diameter of apertures; never more than two rows on a branch; those near bifurcations often irregularly spaced. Peristomes low, inconspicuous. Carina prominent, rounded or angular, bearing regularly spaced low nodes.

Reverse: Branches rounded, without nodes, occasionally delicately striated. Dissepiments thin, rounded, not depressed below plane of branches. Fenestrules elongate, not emarginated, slightly more circular than on obverse face.

Internal structure: Zooecia irregularly kidney-shaped, roughly alternating in position. Superior hemisepta strongly developed, often dividing anterior part of zooecia.

Remarks.—This species has very definite similarities to the species of *Fenestrellina* in the Hamilton formations. It differs from *F. angustata* (Hall) and *F. emaciata* (Hall) in the absence of nodes on the reverse face; from *F. marcida* (Hall) by having wider and more nearly circular fenestrules as well as weaker nodes on the carinae. It differs from *F. quadrangula* (Hall) in having more elliptical fenestrules, fewer and more distant-spaced apertures.

Type.—Holotype and paratypes deposited in the United States National Museum.

Occurrence.—Tully formation, West Brook member, West Brook, 3 miles south of Sherburne, Chenango County, New York.

FENESTRELLINA IRREGULARIS McNair, n. sp.
Plate 45, figures 4, 5, 6; plate 46, figure 1

Zoarium an irregular flabellate expansion.

Obverse: Branches irregular, angular, seldom parallel; average width 0.18 mm.; five in space of 3 mm. Dissepiments slender, rounded; depressed below plane of branches; irregular in length and interval; separated by distances approximately 1.8 mm. Fenestrules large, rectangular to triangular in outline; often inflected by apertures; average length 1.8 mm.; average width 0.45 mm. Apertures small, circular; average diameter 0.09 mm.; opening laterally; 12 in space of 3 mm.; separated by distances two or three times diameters of apertures; never more than two rows on a branch. Peristomes low, inconspicuous, carina low.

Reverse: Branches rounded, occasionally striated. Dissepiments thin, rounded, not depressed below plane of branches. Fenestrules irregularly rectangular in outline, usually emarginated.

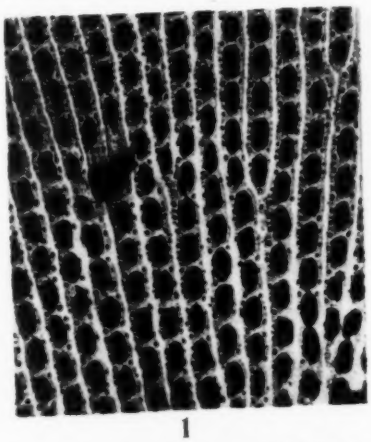
Internal structure: Zooecia triangular in

EXPLANATION OF PLATE 45

All figures ×7½

FIGS. *1–3, 7—Fenestrellina cooperi* McNair, n. sp. *1*, Obverse face of holotype, U. S. Nat. Mus. *2*, Reverse face of paratype showing delicately striated branches, U. S. Nat. Mus. *3*, Obverse face of paratype showing distant-spaced apertures and low carinae, U. S. Nat. Mus. *7*, Reverse face of paratype showing straight, smooth, branches, U. S. Nat. Mus. All specimens from Tully formation, West Brook member, West Brook, N. Y. (p. 344)

4–6—Fenestrellina irregularis McNair, n. sp. *4*, Holotype, obsverse face showing irregular fenestrules and branches, U. S. Nat. Mus. *5*, Paratype, reverse face showing emarginated fenestrules, U. S. Nat. Mus. *6*, Reverse face of paratype showing striated branches, U. S. Nat. Mus. All specimens from Tully formation, West Brook member, West Brook, N. Y (p. 344)



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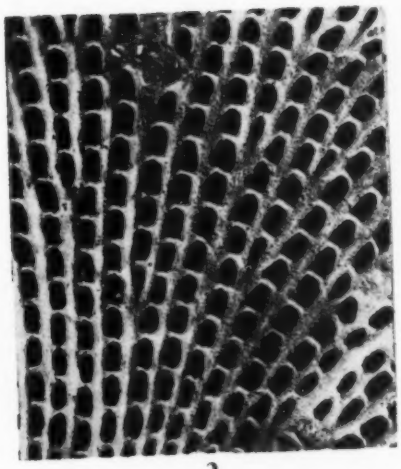

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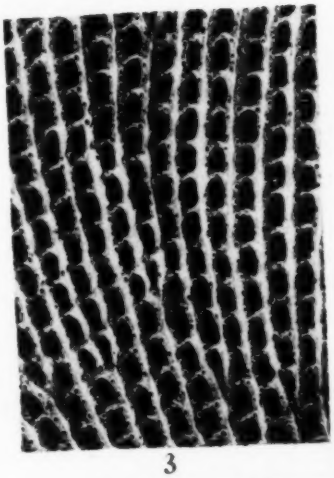

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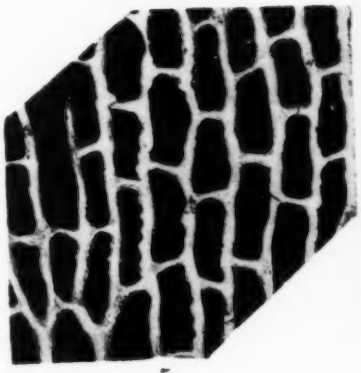

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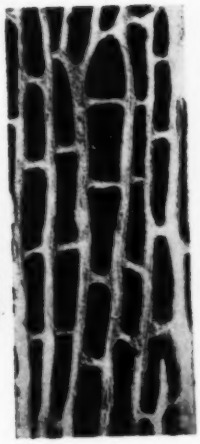

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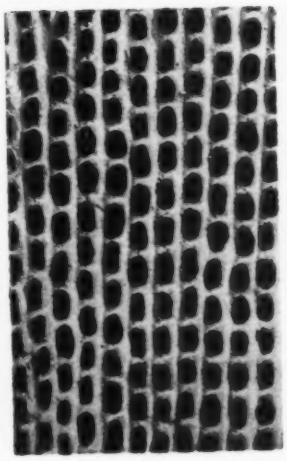

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McNair, Upper Devonian Bryozoa

outline, alternating in position. Median line composed of inner walls of alternating zooecia connected to outer walls by solid rectangular calcareous deposits.

Remarks.—This species might be confused with a number of large fenestruled Fenestrellinas that have been described from the Devonian. It differs from *F. cultrata* (Hall) from the Jeffersonville limestone in having a much less projected carina; from *F. dispanda* (Hall) of the Onondaga in having longer fenestrules with more apertures on their sides. It can be distinguished from *F. planiramosa* (Hall) from the Hamilton in having wider fenestrules, lower peristomes, less prominent carina, and in the absence of more than two ranges of apertures on branches before bifurcation.

Type.—Holotype and paratypes deposited in the United States National Museum.

Occurrence.—Tully formation, West Brook member, West Brook, 3 miles south of Sherburne, Chenango County, New York.

Genus POLYPORA McCoy

POLYPORA BASSLERI McNair, n. sp.

Plate 46, figures 4, 5

Zoarium a flabellate expansion.

Obverse: Branches rounded, sometimes parallel; average width 0.25 mm.; six in space of 3 mm. Dissepiments short, slender, rounded; depressed below plane of branches, separated by distances of approximately 0.45 mm. Fenestrules small, elliptical to circular in outline; never inflected by apertures; average length 0.36 mm.; average width 0.21 mm. Apertures small, circular; average diameter 0.10 mm.; opening directly; separated by distances two to three times diameter of apertures; arranged in slightly zigzag longitudinal ranges; two to four ranges on branch; ranges separated by delicate intermittent sinuous longitudinal ridges. Peristomes circular, low.

Reverse: Not well known because of poorly preserved specimens available, apparently with angular, carinated branches and dissepiments and larger fenestrules than those of obverse face.

Remarks.—On first study this species appears to be related to if not identical with many previously described Devonian species. It differs from them however in minor details. It can be distinguished from *P. celsipora* (Hall) from the Onondaga in having slightly sinuous ranges of apertures and complete absence of indented fenestrules. It differs from *P. flabelliformis* (Hall) in its rounded fenestrules and shorter dissepiments and can be distinguished from *P. fistulata* (Hall) because it has much more weakly developed ridges between ranges of apertures.

Type.—Holotype and paratype deposited in the United States National Museum.

Occurrence.—Tully formation, West Brook member, West Brook, 3 miles south of Sherburne, Chenango County, New York.

Genus SEMICOSCINIUM Prout

SEMICOSCINIUM FLABELLUM McNair, n. sp.

Plate 46, figures 6, 7

Zoarium funnel-shaped, celluliferous on outer side.

Obverse: Branches angular, sinuous, never parallel; average width 0.3 mm.; 5 in space of 3 mm. Dissepiments short, depressed below plane of branches, alternating on sides of branches; separated by distances of approximately 0.9 mm. Fenestrules elliptical to circular in outline; never inflected by apertures; average length 0.6 mm.; average width 0.4 mm. Apertures large, circular; average diameter 0.12 mm.; opening laterally; separated by distances one or two times diameters of apertures. Peristomes low, inconspicuous. Carina high, thin, sinuous; apparently not expanded at summit; broken on most specimens.

Reverse: Branches rounded, flexuous, difficult to distinguish from dissepiments. Dissepiments rounded, short, not depressed below plane of branches. Branches and dissepiments marked by numerous shallow pores surrounded by low peristomes.

Remarks.—This species seems to resemble most closely *Semicoscinium striata* (Hall) and may prove to be a variety of that species. It differs from figured specimens of *S. striata* in having pores rather than nodes on the reverse face. It differs from other specimens of *Semicoscinium* in lacking the expanded summits of carinae and because it has pores on the reverse face.

Type.—Holotype and paratype deposited in the United States National Museum.

Occurrence.—Tully formation, West Brook

member, West Brook, 3 miles south of Sherburne, Chenango County, New York.

Genus SULCORETEPORA d'Orbigny

SULCORETEPORA WILLARDI
McNair, n. sp.
Plate 47, figures 1, 4, 5

Zoarium of bifurcating branches; distance between divergence of new branches 5 to 17 mm. Branches straight or curved, flat; width 2 to 4 mm. Apertures opening directly outward; subcircular to elliptical in outline; average length 0.25 mm.; average width 0.15 mm.; largest at margins of branch; eight in space of 3 mm.; separated longitudinally by distances greater than length of apertures, being closest at points of origin of new ranges; separated transversely by distances approximately equal to widths of apertures. Peristomes sharp, thin. Lunaria not observed, apparently absent. New ranges arise by alternate offsetting of apertures. Ranges often terminating at margin of branch. Six to thirteen ranges on a branch. Ridges between ranges straight, prominent, rounded; separated by average distance of 0.3 mm. Margin not poriferous; edge rounded in cross section.

Remarks.—Sulcoretepora willardi occurs in great abundance in the upper part of the Trimmers Rock sandstone of the Fort Littleton formation of south-central Pennsylvania. The strongly rounded longitudinal ridges and the large marginal apertures distinguish it from Middle Devonian species. The manner of growth of the zoaria varies considerably, ranging from a rapidly branching, curved zoarium to one with straight, far-spaced bifurcations.

Type.—Holotype and paratype deposited in the United States National Museum.

Occurrence.—Fort Littleton formation, upper part of Trimmers Rock sandstone member, road cut on route 433 immediately south of Sweedburg on the county line between Lebanon and Schuylkill Counties, Pennsylvania. Cut on Pennsylvania Railroad, one mile south of Maryville on the Susquehanna River, Perry County, Pennsylvania.

SULCORETEPORA CHADWICKI
McNair, n. sp.
Plate 46, figure 3; plate 47, figures 2, 3

Zoarium of bifurcating branches; distance between divergence of new branches 12 to 25 mm. Branches straight, flat; width 2 to 3.5 mm. Apertures opening directly outward; subcircular to elliptical in outline; average length 0.20 mm.; average width 0.15 mm.; slightly larger at margins of branch than at center; seven in space of 3 mm.; separated longitudinally by distances two to three times diameter of apertures; not particularly crowded at points of origin of new ranges; separated transversely by distances approximately equal to widths of apertures. Peristomes sharp. Lunaria not observed, apparently absent. New ranges arise by alternate offsetting of apertures. Old ranges often terminate at margin of branch. Five to eleven ranges occur on a branch. Ridges be-

EXPLANATION OF PLATE 46

FIG. *1*—*Fenestrellina irregularis* McNair, n. sp. Thin section of paratype, ×30, showing triangular zooecia and regular zigzag line made by inner walls of zooecia and the rectangular calcareous blocks on the margins of the branches. U. S. Nat. Mus. Tully formation, West Brook member, West Brook, N. Y. (p. 344)

2—*Fenestrellina cooperi* McNair, n. sp. Thin section of paratype, ×30, showing irregular zooecia and hemisepta in the anterior ends of zooecia. U. S. Nat. Mus. Tully formation, West Brook member, West Brook, N. Y. (p. 344)

3—*Sulcoretepora chadwicki* McNair, n. sp. Thin section of paratype, ×30, showing apertures (lower part) and acuminate zooecia with solid calcareous deposits in their anterior portions in upper part of figure. Tully formation, West Brook member, West Brook, N. Y. (p. 346)

4–5—*Polypora bassleri* McNair, n. sp. *4*, Obverse face of holotype, ×7½, showing upper part of zoarium with straight branches, U. S. Nat. Mus. *5*, Obverse face of paratype, ×7½, showing lower part of zoarium with diverging branches and enlarged fenestrules; note faint longitudinal striations on branches; U. S. Nat. Mus. Tully formation, West Brook member, West Brook, N. Y. (p. 345)

6–7—*Semicoscinium flabellum* McNair, n. sp. *6*, Reverse face of paratype, ×7½, showing character of branches and dissepiments and pores, U. S. Nat. Mus. *7*, Obverse face of holotype, ×7½, showing sinuous branches, carina broken, U. S. Nat. Mus. Tully formation, West Brook member, West Brook, N. Y. (p. 345)

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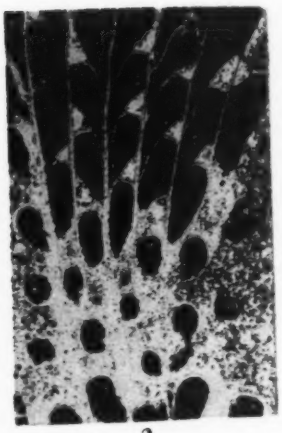

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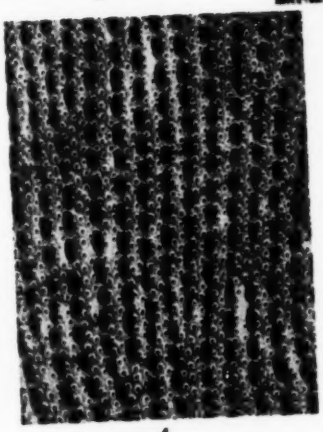

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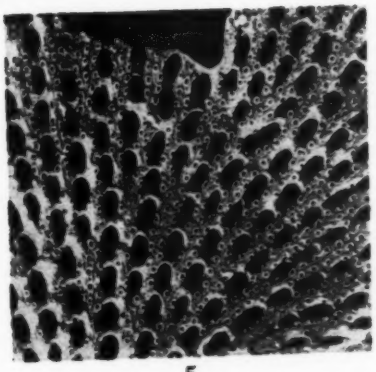

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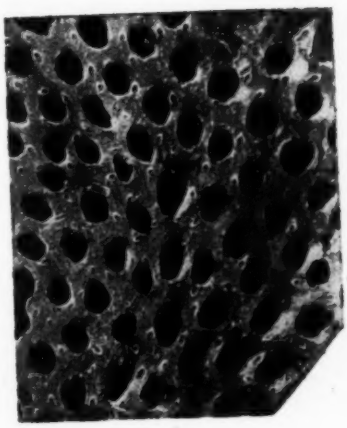

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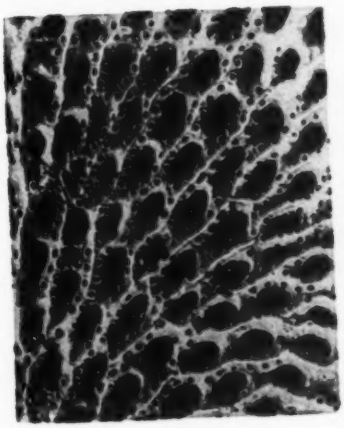

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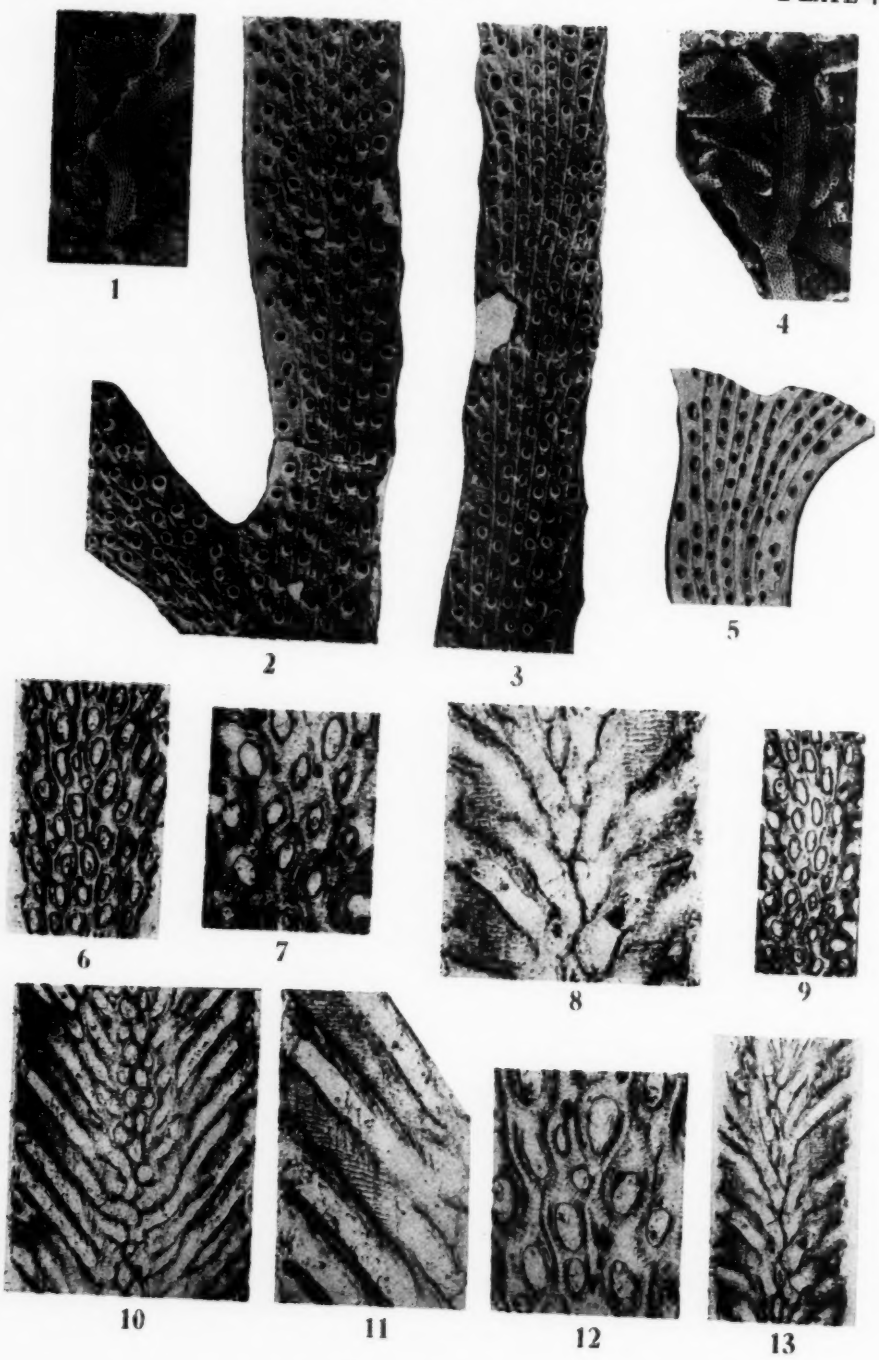
McNair, Upper Devonian Bryozoa



McNair, Upper Devonian Bryozoa

tween ranges straight, prominent, rounded; separated by average distance of 0.24 mm.; sometimes terminate at margin of branch. Margin not poriferous, narrow, angular in cross section.

Internal structure: Zooecia obovate-acuminate with massive calcareous plates in their anterior portions, interzooecial apertures few or wanting.

Remarks.—This species has many characteristics in common with *Sulcoretepora incisurata* (Hall), *S. obliqua* McNair and *S. hamiltonensis* (Ulrich) of the Hamilton of New York, Michigan and Iowa, respectively. It differs from these, however, in having more distant spaced apertures, usually weaker longitudinal ridges and lack of interzooecial vesicles.

Type.—Holotype and paratypes deposited in the United States National Museum.

Occurrence.—Tully formation, West Brook member, West Brook, 3 miles south of Sherburne, Chenango County, New York.

Genus ORTHOPORA Hall
ORTHOPORA? MAGNA McNair, n. sp.
Plate 47, figures 6, 10–12

Zoarium ramose, of cylindrical bifurcating branches. Branches straight or slightly curved; distance between bifurcations as great as 25 mm.; angle between branches 45° to 70°; thickness approximately 1.5 mm. Apertures opening obliquely outward, elliptical in outline; average length 0.17 mm.; average width 0.10 mm.; eight in space of 2 mm. along length of branch; separated longitudinally by distances from one-half to approximately length of aperture and transversely by distances approximately equal to width of aperture; situated in sinuous longitudinal ranges, separated by sinuous ridges; apertures in adjacent ranges alternate in position. Peristomes absent; apertures situated in elongate hexagonal depressions between sinuous longitudinal ridges. Acanthopores small, few, less numerous than zooecia. Zooecial walls laminated; laminations normal to long axis of branch in longitudinal sections, approximately normal to longitudinal ridges in tangential sections; not thickened in peripheral region. Zooecia tubular, oblique, apparently diverging from an axial filament.

Remarks.—In defining *Orthopora*, Hall did not include a discussion of its internal structure. This species agrees in general to the external characters of Hamilton species figured by Hall, excepting that there are fewer acanthopores, and that the arrangement of ranges of apertures and longitudinal ridges is more nearly longitudinal in this than in most of Hall's species. *Orthopora magna* differs from *O. acuta*, n. sp., in having a much larger diameter and having tubular zooecia without expanded walls in the peripheral region.

Type.—Holotype 22653 Carnegie Museum.

Occurrence.—Chemung? Bank of Black Creek near Rockville Lake, Rockville, Allegany County, New York. Specimens collected by E. R. Eller.

EXPLANATION OF PLATE 47

FIGS. *1, 4, 5—Sulcoretepora willardi* McNair, n. sp. *1*, Holotype, ×2, showing part of zoarium with numerous branches, U. S. Nat. Mus. *4*, Paratype, ×2, showing distant bifurcations and straight branches, U. S. Nat. Mus. *5*, Camera-lucida drawing of portion of holotype, ×7½, showing surface details, U. S. Nat. Mus. Fort Littleton formation, Trimmers Rock member, 1 mile south of Maryville, Perry County, Penn. (p. 346)

2, 3—Sulcoretepora chadwicki McNair, n. sp. *2*, Holotype, ×7½, showing part of zoarium with longitudinal ridges which do not extend to the margin of branch, U. S. Nat. Mus. *3*, Paratype, ×7½, showing serrate margined branch, specimen from immature part of zoarium, U. S. Nat. Mus. Tully formation, West Brook member, West Brook, N. Y. (p. 346)

6, 10–12—Orthopora? magna McNair, n. sp. *1*, Holotype, ×20, tangential section showing arrangement of zooecia and acanthopores, Carnegie Mus. 22653. *10*, Holotype, ×20, longitudinal section showing straight zooecia with laminated walls and axial region. *11*, Holotype, ×40, showing wall structure in longitudinal section. *12*, Holotype, ×40, showing wall structure in tangential section. Chemung? Near Rockeville, Allegany County, N. Y. (p. 347)

7–9, 13—Orthopora? acuta McNair, n. sp. *7*, Holotype, ×40, tangential section showing wall structure, Carnegie Mus. 22654. *8*, Holotype, ×40, showing thickened interapertual spaces with acanthopores and laminated walls. *9*, Tangential section of holotype, ×20, showing arrangement of zooecia and acanthopores. *13*, Longitudinal section of holotype, ×20. Chemung? Belmont, Allegany County, N. Y. (p. 348)

ORTHOPORA? ACUTA McNair, n. sp.
Plate 47, figures 7–9, 13

Zoarium ramose, of cylindrical irregularly bifurcating branches. Branches straight or flexuous; distance between bifurcations unknown, in some instances greater than 20 mm.; thickness approximately 0.9 mm. Apertures opening obliquely outward, elliptical in outline; average length 0.12 mm.; average width 0.5 mm.; eight in space of 2 mm. along length of branch; separated by distances from one and a half to two times length of aperture; situated in sinuous longitudinal ranges, separated by low longitudinal ridges. Acanthopores small, few, slightly less numerous than zooecia. Zooecial walls laminated normal to long axis of branch in longitudinal sections and approximately normal to longitudinal ridges in tangential sections; not thickened in peripheral region. Zooecia tubular. Interzooecial spaces expanded in peripheral region.

Remarks.—This species differs from *Orthopora magna*, n. sp., in being much smaller in diameter, having smaller apertures, relatively more numerous acanthopores and expanded interzooecial walls in the peripheral region.

Type.—Holotype 22654; paratype 22655 Carnegie Museum.

Occurrence.—Chemung? Belmont, New York, bank of Genessee River between Liberty Highway bridge and Railroad Bridge, Allegany County, New York. Specimens collected by E. R. Eller.

Family HETEROTRYPIDAE Ulrich
Genus HYALOTOECHUS McNair, n. gen.

Zoarium ramose. Walls thin in axial zone, thickened abruptly, becoming massive in mature zone; clear nongranular; of laminated zooecial deposits separated by amalgamate medial band. Zooecia oval or polygonal. Diaphragms absent; heterophragms present on proximal part of walls in early mature region. Mesopores absent; small zooecia occasionally present. Acanthopores well defined, seldom numerous.

Genotype, *Hyalotoechus duncani* McNair, n. sp.

Remarks.—The three species placed in this genus exhibit typical heterotrypid wall structure, a characteristic of all members of the family Heterotypidae. The genus differs from all previously defined genera of the family in having heterophragms on the proximal walls of the zooecia in the early part of the mature region and in having abruptly thickened walls in the mature zone. This thickening in some instances simulates the walls of certain Cryptostomata. Helen Duncan has generously inspected the specimens on which the genus is based and has stated that they form a new group of the Heterotrypidae.

HYALOTOECHUS MINIMUS McNair, n. sp.
Plate 48, figures 1, 7

Zoarium ramose; average diameter 5 mm. Monticules not observed. Zooecia oval; average length 0.20 mm.; average width 0.1; seven in 2 mm.; occasionally one is much smaller than average. Acanthopores small, not numerous. Zooecia direct; bending abruptly at mature zone; almost at right angles at surface. Walls thin in axial, thick in mature zones. Heterophragms few, short and inconspicuous; occurring on proximal walls of early mature zone.

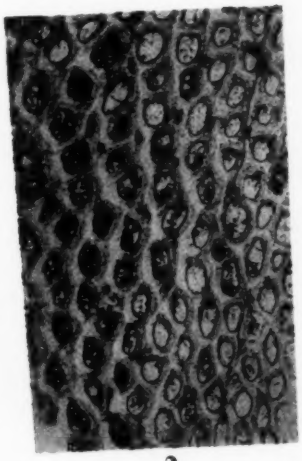
EXPLANATION OF PLATE 48

FIGS. *1*, *7*—*Hyalotoechus minimus* McNair, n. sp. *1*, Holotype, ×20, longitudinal section showing short, direct mature zone and heterophragms at junction of axial and mature zones, Carnegie Mus. 22656. *7*, Tangential section, ×20, holotype, showing clear walls, arrangement of zooecia and acanthopores. Chemung? Two miles south of Scio, N. Y. (p. 348)

2–4, *6*—*Hyalotoechus duncani* McNair, n. sp. *2*, Holotype, ×20, tangential section showing clear walls, arrangement of zooecia and acanthopores, Carnegie Mus. 22657. *3*, Holotype, ×20, longitudinal section showing oblique zooecia, thickened mature zone, heterophragms obscure. *4*, Paratype, ×20, tangential section showing region of small zooecia, Carnegie Mus. 22658. *6*, Paratype, ×20, showing oblique zooecia and heterophragms at junction of axial and mature zones. Chemung? McHenry Creek, ½ mile north of Five Corners, Allegany County, N. Y. (p. 349)

5, *8*—*Hyalotoechus elleri* McNair, n. sp. *5*, Holotype, ×20, tangential section showing arrangement of zooecia and acanthopores, Carnegie Mus. 22659. *8*, Holotype, ×20, longitudinal section showing long mature zone with thick walls. McHenry Creek, ½ mile north of Five Corners, Allegany County, N. Y. (p. 349)

1



2

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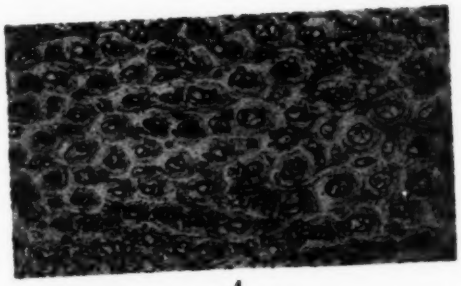

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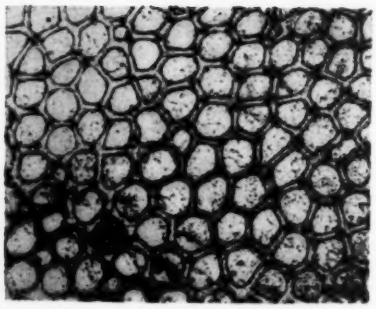
8

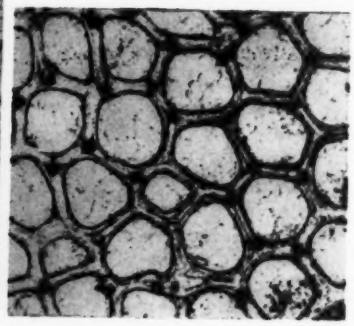
McNair, Upper Devonian Bryozoa

1



2

3



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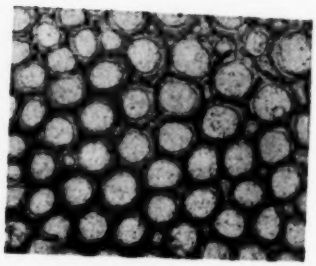

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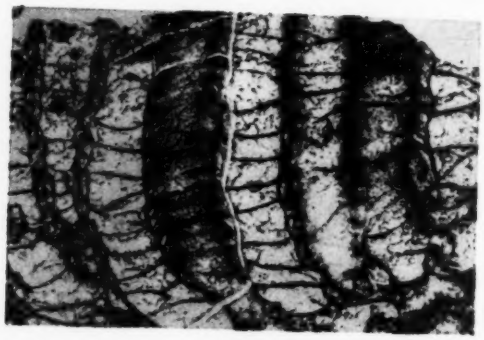
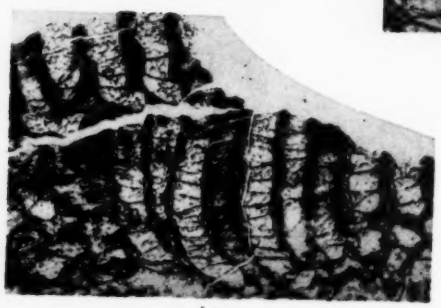
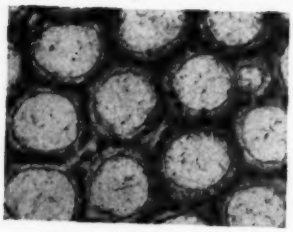


6



7



8

McNair, Upper Devonian Bryozoa

Remarks.—This species differs from others associated with it in having a short mature zone with the zooecia opening directly to the surface.

Type.—Holotype 22656 Carnegie Museum.

Occurrence.—Chemung? Vandermark Creek, 2 miles from Scio, New York; lower part of gorge in Railroad Valley, 2 miles south of Alfred Station, New York. Specimens collected by E. R. Eller.

HYALOTOECHUS DUNCANI McNair, n. sp.
Plate 48, figures 2–4, 6

Zoarium ramose; average diameter 5 mm. Monticules not observed. Zooecia oval; average length 0.25 mm.; average width 0.15 mm.; eight in 2 mm. Acanthopores small, not numerous. Zooecia oblique; slightly less oblique in mature than in axial region. Walls thin in axial and thick in mature region. Heterophragms few, short, inconspicuous; occurring on proximal walls of early mature zone.

Remarks.—This species occurs most abundantly in collections from southwestern New York. It differs from other species in having oblique zooecial tubes and larger zooecia.

Type.—Holotype 22657; paratype 22658 Carnegie Museum.

Occurrence.—Chemung? Vandermark Creek, two miles from Scio, New York; lower part of gorge in Railroad Valley, 2 miles south of Alfred Station, New York. Specimens collected by E. R. Eller.

HYALOTOECHUS ELLERI McNair, n. sp.
Plate 48, figures 5, 8

Zoarium ramose; diameter 2 to 5 mm. Monticules not observed. Zooecia oval to circular; average length 0.17 mm.; average width 0.10 mm.; eight in 2 mm. Acanthopores few, occasionally numerous. Zooecia direct, bending abruptly at early mature region. Walls thin in axial and thick for considerable distance in mature region. Heterophragms few, short, inconspicuous; occupying proximal zooecial walls of early mature zone.

Remarks.—This species differs from *Hyalotoechus duncani*, n. sp. and *H. minimus*, n. sp., in having a longer mature region and relatively more acanthopores.

Type.—Holotype 22659 Carnegie Museum.

Occurrence.—Chemung? McHenry Creek bed, ½ mile north of Five Corners, Canaseraga Quadrangle, Allegany County, New York; lower part of gorge in Railroad Valley, 2 miles south of Alfred Station, New York. Specimens collected by E. R. Eller.

Family BATOSTOMELLIDAE Ulrich
Genus STEREOTOECHUS Duncan
STEREOTOECHUS IRREGULARIS McNair, n. sp.
Plate 49, figures 1–4

Zoarium laminar, of superimposed layers forming irregular masses with kidney-shaped projections. Zooecia subpolygonal to circular; average diameter 0.20 mm.; eight in 2 mm.; apparently not arranged in clusters. Walls thick, amalgamate, nongranular. Acanthopores well defined; located at junction of zooecial walls. Zooecia direct; walls periodically thickened. Diaphragms numerous, one-half to two tube diameters apart.

Remarks.—This species differs from *Stereotoechus typicus* Duncan in its more irregular walled, larger, and more nearly polygonal zooecia. The close relationship between the two may indicate affinities of upper Traverse faunas to those of the Upper Devonian of Iowa.

Type.—Holotype 2799 State University of Iowa.

Occurrence.—Shellrock formation, Mason City dolomite member, SW. ¼, NE. ¼, sec.

EXPLANATION OF PLATE 49

FIGS. *1–4*—*Stereotoechus irregularis* McNair, n. sp. *1*, Holotype, ×20, longitudinal section showing thickened zooecial walls, State U. Iowa 2799. *2*, Holotype, ×20, tangential section showing clear walls, polygonal zooecia and acanthopores. *3*, Holotype, ×40, showing wall structure. *4*, Tangential section of holotype, ×40, showing wall structure. Shellrock formation, Mason City dolomite, sec. 7, T. 96 N., R. 18 W., Floyd County, Iowa. (p. 349)

5–8—*Eostenopora rugosa* McNair, n. sp. *5*, Holotype, ×20, tangential section showing circular zooecia and granular acanthopores, State U. Iowa 2798. *6*, Longitudinal section of holotype, ×40, showing thickened walls and numerous diaphragms. *7*, Longitudinal section, ×20, holotype. *8*, Tangential section, ×40, holotype, showing wall structure. Shellrock formation, Mason City dolomite, sec. 7, T. 96 N., R. 18 W., Floyd County, Iowa. (p. 350)

17, T. 96 N., R. 18 W., Floyd County, Iowa. Specimens collected by C. H. Belanski.

Genus EOSTENOPORA Duncan
EOSTENOPORA RUGOSA McNair, n. sp.
Plate 49, figures 5–8

Zoarium incrusting, forming small lobate masses. Zooecia circular; average diameter 0.20 mm.; six in 2 mm. Mesopores absent; smaller zooecia rare. Walls thick, laminated, granular; intermittently thickened, approaching a beaded condition; usually occupied by single series of closely arranged granular acanthopores. Zooecia curved, direct; consisting almost completely of mature zone. Diaphragms thin, distributed equally throughout zoeecia by distance less than tube diameter.

Remarks.—This species appears to be most closely related to *Eostenopora tenuimuralis* Duncan. It can be distinguished from the Traverse species, however, by its thicker walls and more circular zooecia.

Type.—Holotype 2798 State University of Iowa.

Occurrence.—Shellrock formation, Mason City dolomite member, SW. ¼, NE. ¼, sec. 17, T. 96 N., R. 18 W., Floyd County, Iowa. Specimens collected by C. H. Belanski.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 3, PP. 351–361, PLS. 50, 51, 1 TEXT FIG., May 1942

LITHOSTROTIONTIDAE IN THE ROCKY MOUNTAINS

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ABSTRACT—Many of the late Paleozoic colonial corals in the Cordilleran region that have been identified as species of *Lithostrotion* Fleming are referred to *Lithostrotionella* Yabe and Hayasaka, and to *Diphyphyllum* Lonsdale. The bases for separation are excessive development of vesicular tissue in the peripheral zone, which resulted in proximal shortening of the septa in *Lithostrotionella*, whereas a distal shortening of all septa resulted in the destruction of a septal but not of a tabular columella in *Diphyphyllum*. Two new species of *Lithostrotionella* and one new species of *Diphyphyllum* are described. A new name, *Diphyphyllum sinuosum* is proposed for *Lithostrotion flexuosum* Warren, a name preoccupied by *L. flexuosum* Trautschold.

INTRODUCTION

COLONIAL corals have been found in the Mississippian and Pennsylvanian strata in Rocky Mountain Paleozoic beds from Utah to northern Canada (fig. 1). Outstanding among these corals are those which usually have been referred to the genus *Lithostrotion* Fleming. Many well-known species previously referred to this genus have recently been said by Hayasaka (1936) to belong to the genus *Lithostrotionella* Yabe and Hayasaka. Indirect confirmation of Hayasaka's opinion is given by Professor Stanley Smith, who says:

> It (*Lithostrotion*) has been recorded and described from Eastern Asia and also from North America, but none of the American forms which I myself have examined, appear to be congeneric with the British types. I do not wish to imply that true *Lithostrotion* may not have been found within that continent (Smith, 1920, p. 53).

Hayasaka (1936) did not deal with fasciculate corals belonging to the Lithostrotiontidae, nor did he make reference to any of the massive corals of that family which had been discovered in the Canadian Rockies. In the present paper the writer describes both fasciculate and massive forms of Lithostrotiontidae from exposures along the headwaters of the Athabasca and Saskatchewan rivers near Jasper, Alberta. In preparing these descriptions he has also studied specimens collected from Mississippian and Pennsylvanian rocks exposed near Banff, Alberta, as well as specimens from Montana, Idaho and Utah, loaned through the courtesy of Dr. Charles Deiss of The University of Montana, Dr. J. Stewart Williams of Utah State Agricultural College, and Miss Phyllis Wilcken of the University of Utah.

The writer is grateful for the loan of these specimens and for the aid received from Dr. G. M. Ehlers of the University of Michigan, who has been very generous in lending specimens from the Museum of Paleontology at Ann Arbor and in making available the facilities of the laboratories of the museum.

SYSTEMATIC DESCRIPTIONS

Family LITHOSTROTIONTIDAE
A. W. Grabau, 1927

Genus LITHOSTROTIONELLA Yabe and Hayasaka, 1915

The genus *Lithostrotionella* was described by Yabe and Hayasaka (1915) as follows:

> Corallum composite, massive, composed of prismatic corallites with lamellar columella; distinguished from *Lithostrotion* by having a vesiculated peripheral zone, well bounded by an inner wall, the inside of which has essentially the same structure with *Lithostrotion*. The septa protruding out of the inner wall soon disappear in the vesiculated zone, without extending to the wall.

This description emphasizes features that are also emphasized by Stanley Smith in his diagnosis of the genus *Aphrophyllum* (Smith, 1920), and it is possible that Smith's genus will prove to be a synonym of *Lithostrotionella*. Both authors agree on the relationship of their genera with *Lithostrotion* rather than with *Lonsdaleia* (see pl. 50. figs. 3, 4), and both authors stress a vesicular peripheral zone, intraperipheral septa, and a simple columella. The prismatic forms described in this paper could be referred to either genus but are grouped under *Lithostrotionella* because that genus has priority.

Occurrences of species of *Lithostrotionella*

throughout the world are given in the list. The genus is well represented in North America and Asia and occurs also in eastern Europe. A similar genus, *Aphrophyllum*, occurs in Australia. *Lithostrotionella* has been found in strata of Mississippian, Pennsylvanian, and Permian age, although most of the recorded species are from the upper Mississippian.

LITHOSTROTIONELLA PENNSYLVANICA (Shimer)

Plate 50, figures 1, 2, 5, 6, 8

Lithostrotion pennsylvanicum SHIMER, *1926*, Canada Geol. Survey Bull. 42, p. 27, pl. 5, figs. 3–5.

The holotype of this species is deposited in the Canadian National Museum but was not available for study. The writer's remarks are therefore based on a specimen from Alberta which answers the description of the species given by Shimer. The identification of this specimen was checked by Professor P. S. Warren, of the University of Alberta, who is familiar with the species.

In his description of *L. pennsylvanica*, Shimer (1925, pp. 27, 28) does not mention the outer vesiculated zone in which the proximal portion of the septa are cut off. The interruption of the septa is, however, very clearly shown in the transverse sections of the specimen upon which the writer's remarks are based. The apparent discrepancy between Shimer's description and the writer's observations may be explained if Shimer's observations were confined to surface features, since the weathered surface of the corallites of the writer's specimen do not suggest incomplete septa. Hayasaka (1936, p. 53) calls attention to similar cases when he says:

> In many of the specimens of *Lithostrotionella* examined the calices are exceedingly well preserved. In these calices the septa are seen as extending from the epitheca to the central part of the corallites. It seems that the septal development has quite often been described on the basis of observation on such calices. However, it must be borne in mind that the calicular features do not indicate the true features of the septal development. The inner surface of the calices represent the last surface of the dissepimental tissue. Therefore, even in the forms of coral in which the septa are not complete, they have the appearance of completeness as they have in many well-preserved specimens of *Lonsdaleia*.

Thin sections cut transverse to the long axis of the corallite of *L. pennsylvanica* clearly show a false inner wall between an outer vesiculated, and an intermediate septate zone, which leaves little doubt as to the generic disposition of the species.

Lithostrotionella pennsylvanica strongly resembles *L. americana* in the well-defined peripheral zone formed by the cystosepiments but differs in the absence of an inner wall formed by the coalescence of the distal ends of the principal septa. From *L. floriformis* it may be distinguished because the principal septa do not penetrate the inner zone. In this latter character *L. pennsylvanica* resembles *L. tubifera*, but *L. pennsylvanica* has larger corallites, and more numerous septa.

The specimens figured form part of the collection of the Museum of Paleontology, University of Michigan, Ann Arbor. Two sections (pl. 50, figs. 2, 6) were cut from an erratic collected on the summit of a hill in the Bragg Creek area, Alberta. Fragments from the same specimen are in the possession of Michigan State College. Their stratigraphic horizon is unknown but is presumed to be in the Pennsylvanian beds that outcrop in the Rocky Mountains west of the locality where the erratic was found. Two other sections (pl. 51, figs. 1, 5) were cut from a specimen collected near Banff, Alberta, by Carl Rominger.

LITHOSTROTIONELLA ASTRAEIFORMIS (Warren)

Diphyphyllum astraeiforme WARREN, *1927*, Canada Geol. Survey Mem. 153, pp. 44–45, pl. 3, figs. 2, 3; pl. 6, fig. 1.

The writer has included Warren's species in the list of occurrences of *Lithostrotionella* without having had the opportunity of studying any specimens. Warren states that he was uncertain of the generic disposition of his specimens, and that he considered assigning them to *Thysanophyllum* because:

> in a transverse section the septa appear to be absent from the dissepimental zone, though the primaries may be observed protruding into the tabulate area.

He dismissed *Thysanophyllum* because

> more careful study showed that the septa were once present in the outer zone and that they had broken down later.

REPORTED OCCURRENCE AND RANGE OF LITHOSTROTIONELLA

	1[1]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
L. americana Hayasaka		M[2]			M	M					M br				M				
L. astraeiformis (Warren)													C r						
L. banffensis (Warren)													C r						
L. castelnaui Hayasaka	M		M n	M g	M	M sc	M ba								X				
L. flexuosa (Trautschold)																			C
L. floriformis Hayasaka																X			
L. girtyi Hayasaka					M st				M			M m			M				
L. hemispherica Hayasaka		M	M g	M g	M st	M st			M		M m								
L. jasperensis Kelly, n. sp.												M br	M r						
L. kueichousensis Yu																	M		
L. macouni (Lambe)														M					
L. micra Kelly, n. sp.													M r						
L. multiradiata Hayasaka									M		M								
L. pennsylvanica (Shimer)												C	C r						
L. simplex Hayasaka									P	C w									
L. spiniformis Yu																	M		
L. stylaxis (Trautschold)																			C
L. tabulata Hayasaka											M br								
L. tubifera Hayasaka												M m							
L. unicum Yabe and Hayasaka																	C		
L. uraica Dobroliubova																		P	
L. vesicularis Hayasaka																X			
L. vesiculosa Dobroliubova																			C
L. sp. (Girty, 1899, p. 513)										M m									
L. sp. (Shimer, 1926) (Gilluly, 1932, p. 24)									M				C r						
L. sp. (Nolan, 1935, p. 31)									m & om										
L. sp. (Hayasaka, 1937)																		P	
L. sp. (Hayasaka, 1937 B)								C											

[1] 1, Alabama (Hayasaka, 1936).
2, Kentucky (Hayasaka, 1936).
3, Virginia (Hayasaka, 1936).
4, W. Virginia (Hayasaka, 1936).
5, Illinois (Hayasaka, 1936).
6, Missouri (Hayasaka, 1936).
7, Michigan (Hayasaka, 1936).
8, Oklahoma (Hayasaka, 1937b)
9, Utah (Hayasaka, 1936).
10, Wyoming (Hayasaka, 1936).
11, Idaho (Hayasaka, 1936).
12, Montana (Ross, 1934; Hayasaka, 1936; Shimer, 1926; Kelly, this paper).
13, Alberta (Shimer, 1926; Warren, 1927; Kelly, this paper).
14, British Columbia (Lambe, 1901).
15, California (Hayasaka, 1936).
16, Alaska (Hayasaka, 1936).
17, China (Hayasaka, 1937a).
18, Ural region (Hayasaka, 1937a).
19, Moscow basin (Hayasaka, 1937a).

[2] M, Mississippian; C, Pennsylvanian; P, Permian; X, system not given; ba, Bayport limestone; br, Brazer limestone; g, Greenbrier limestone; m, Madison limestone; n, Newman limestone; om, Ochre Mountain; ru, Rundle limestone; sc, Seneca chert; st, St. Louis limestone; w, Weber quartzite.

OCCURRENCE AND RANGE OF DIPHYPHYLLUM AND LITHOSTROTION S.L. IN THE CORDILLERAN REGION

Diphyphyllum	1[1]	2	3	4	5	6	7a	7b	8a	8b
D. mutabile Kelly					M[2] br			M ru		
D. sinuosum Kelly				M br			C? ru	M ru		
D. sp. (this paper)								M ru		
D? sp. (Noble, 1923)		M re								
Lithostrotion (sensu lato)										
L. harmodites Edwards and Haime?	M mc			M br						
L. cf. *L. irregulare* (P.)										P
L. martini Edwards and Haime				M br						
L. portlocki McCoy				M br?						P
L. whitneyi Meek	M		M	M br	M br		C ru			
L. sp. (Daly, 1912)						M m				
L. sp. (Umpleby, 1913)				M br						
L. sp. (Gilluly, 1932)			M m							
L. sp. (Nolan, 1935)			M m							
L? sp. (Cairnes, 1914)									M	
L? sp. (Cairnes, 1915)	M								C	
L? sp. (Hewett, 1931)	mc C									
L? sp. (Hewett, 1931)	bs M									
L? sp. (Westgate and Knopf, 1932)	ps									
L? sp. (Mertie, 1937)										M cb

[1] 1, Nevada (White, 1877; Hewett, 1931; Westgate and Knopf, 1932).
2, Arizona (Noble, 1923).
3, Utah (Meek, 1877; Gilluly, 1932; Nolan, 1935).
4, Idaho (Umpleby, 1913; Mansfield, 1927; Ross, 1930).
5, Montana (Kelly, this paper).
6, British Columbia (Daly, 1912).
7a, Alberta-Banff area (Warren, 1927).
7b, Alberta-Mountain Park area (Kelly, this paper).
8a, Yukon Territory (Cairnes, 1914, 1915).
8b, Alaska (Mertie, 1937; Moffit, 1938).

[2] M, Mississippian; C, Pennsylvanian; P, Permian; br, Brazer limestone; bs, Bird Spring formation; cb, Calico Bluff formation; m, Madison limestone; mc, Monte Cristo limestone; ps, Peers Spring; re, Redwall; ru, Rundle limestone.

This latter statement parallels that made by Hayasaka (1936, p. 53) for *Lithostrotionella* and *Lonsdaleia* and would also hold for *Thysanophyllum*, which differs from *Lithostrotionella* principally in the reduction of the columella. Warren's reference of his species to *Diphyphyllum* implies the absence of a columella, but inasmuch as this structure is not always well developed (see *L. pennsylvanica* and *L. micra*, pl. 50, fig. 7) and specimens of the species are few in number, it seems safer to refer the species to *Lithostrotionella*, which is better known in North America than is *Thysanophyllum*.

LITHOSTROTIONELLA BANFFENSIS (Warren)

Lithostrotion banffense WARREN, *1927*, Canada Geol. Survey Mem. 153, p. 46, pl. 4, figs. 5, 6; pl. 5.

The holotype of this species is deposited in the Canadian National Museum, but, as it is not available for study, the description

FIG. 1—Reported occurrences of *Lithostrotionella* in North America. Occurrences of *Diphyphyllum* and *Lithostrotion* s.l. are shown only for the Cordilleran region.

is based upon a specimen obtained from Professor Warren. Warren's description of the type follows:

Corallum compound, massive; size and shape unknown; surface irregular. Corallites crowded, polygonal, slightly flexuous, varying greatly in diameter in the same colony; width from 3 to 11 mm., averaging about 6 mm. Exterior surface with transverse wrinkles irregularly spaced, about 6 in 10 mm., also with longitudinal ridges (costae). Calyx shallow, outer area sloping gently inwards; central area vertically depressed into a cup-shaped cavity about 2 mm. deep and about one-third the diameter of the corallite in width; bottom of cavity slightly convex. Columella small, slightly compressed, piercing the floor of the central cavity and rising nearly to its top.

Primary septa 20, reaching nearly or quite to the columella; secondary septa alternating with the primaries, short, not reaching beyond the dissepimental zone. Tabulae numerous, about four in 2 mm., upwardly arched, convex externally and concave internally; vertical section of one-half a tabula is a sigmoid sloping upward; angle over the summit about 90°. Dissepiments occurring in a single series, confined to the outer zone, arising at right angles from the outer wall, curving inward and downward, the inner extremities being almost parallel to the wall; each dissepiment, as seen in vertical section, being practically a quarter of a circle.

Warren did not call attention to the series of cystosepiments in the peripheral area of *Lithostrotionella banffensis*. The sketch of a transverse section of his species that appears as figure 5 of his plate 3 is incomplete and gives an incorrect view of the appearance of the corallite (Warren, 1939). The figure fails to show any type of dissepimental tissue, although the description and figure 6 (which is numbered 9 on the plate because the figure has been inverted) of the same plate indicates the presence of either dissepiments or cystosepiments. Examination of the specimen obtained from Professor Warren clearly shows that the ends of the septa do not reach the theca, and there seems little doubt that this species should be assigned to the genus *Lithostrotionella*.

LITHOSTROTIONELLA JASPERENSIS
Kelly, n. sp.
Plate 51, figs. 3, 6

The corallum of this form is unknown, fragments only being available for study. The corallites are prismatic and vary considerably in diameter. This variation may be explained if the fragments came from the base of a corallum in which budding was active. The obliquity between the axes of the corallites lends some support to such an inference. The diameter of an average corallite is about 12 mm. but ranges from 7 to 14 mm.

Longitudinal section: The corallite is distinctly divided into three zones. The outer zone of cystosepiments occupies about one-fifth of the total width of the corallite and is commonly formed of two series of cystosepiments. The longer cystosepiments are moderately convex and curve inward sharply to their junction with the tabulae. Shorter cystosepiments are inserted irregularly between the longer ones and intersect them within the outer zone. There are about 10 long cystosepiments in 5 mm. and about half that number of short cystosepiments. The tabulae are pointed near the columella and slope with little curvature in the central zone, which occupies about one-half of the corallites. At the edge of the central zone the tabulae are abruptly deflected downward, but they are flattened again where they are contiguous with the cystosepiment. There are about 10 tabulae in 5 mm., although the number is variable because of irregular branching and intersecting. The columella is distinct only in sections transverse to the plane of symmetry. It is apparently formed from the thickened end of the counter-septum. The relatively wide projection in the unsectioned calyx is formed from the upturned central portion of the tabulae.

Transverse section: The boundary between the outer vesiculated and intermediate septate and dissepimental zone is moderately distinct, there being examples of septa projecting outward into a zone which, traced laterally, is occupied only by septal spines. There are 20 to 22 long flexuous septa and an equal number of tertiary septa in the intermediate dissepimental zone, but only the principal septa penetrate the central zone. Within the central zone the septa converge towards cardinal and counter septa, which thicken at the center and, together with the central portion of the upraised tabulae, form the columella.

Lithostrotionella jasperensis differs from *L. banffensis* principally in the relatively greater length of the secondary septa. The shape of the tabulae is also different, since they slope downward without any marked change of curvature from the columella in *L. banffensis*, whereas they are flattened in the central area of *L. jasperensis* and then end abruptly near the edge of the central area. *L. jasperensis* differs from *L. tabulata* in the larger size of its corallites and in the character of its tabulae, which are said to be flat in *L. tabulata*.

Age and locality.—The holotype was collected just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta. This coral is associated with the fauna char-

acteristic of the uppermost Mississippian strata of the Mountain Park area. It also occurs on Lindsay Creek in the same area. The species appears to be identical with a specimen from the Brazer formation at Hannah Gulch, Montana, loaned through the courtesy of Dr. Charles Deiss.

Holotype.—Canadian National Museum at Ottawa, Canada.

LITHOSTROTIONELLA MICRA Kelly, n. sp.
Plate 50, figure 7

Entire corallum unknown. Fragments of the corallum indicate a gently curving upper surface of small prismatic corallites. The average diameter of the corallites is under 4 mm.

Longitudinal section: Each corallite is distinctly divided into three zones, the outer or peripheral zone forming about one-fourth of the total width of the corallite and being commonly composed of one prominent series of convex cystosepiments, which are inclined abruptly near their junction with the tabulae. Because of some smaller cystosepiments the spacing is irregular, there being about six or seven in a space of 5 mm. Sections cut through the axis of the corallites indicate flat tabulae except near the center, where they are domed upwards, and near the outer border of the tabulae, which are depressed downward to meet the adjacent cystosepiments. There are about 13 tabulae in a space of 5 mm. An axial structure, formed by the upturned central portion of the tabulae, shows in all mesial sections, but a septal columella is not present in all corallites.

Transverse section: The boundary between the outer vesiculated zones and the intermediate septate zone is sharp. A few septal spines are present in the outer zone, which contains a few relatively large cystosepiments. In the intermediate zone there are about 26 to 30 alternating long and short flexuous septa. The dissepiments in the intermediate zone are few and, together with the curved distal ends of the longer septa, form, in some corallites, an inner zone free of septa. The columella is formed by the enlargement of the distal end of the counter septa. In other sections the cardinal and counter septa join to form a thin, weak columella. In still other sections the septa fail to reach the center of the corallite, and the axial region is occupied by the truncated portion of the upturned tabulae.

Remarks.—The small size of the corallites in this species distinguishes it from such forms of *Lithostrotionella* as *L. tubifera*, *L. tabulata*, and *L. simplex*. In addition our Mountain Park species lacks the central tube which is regarded as diagnostic of *L. tubifera*. It differs from *L. tabulata* in the possession of more numerous septa, and from *L. simplex* in the possession of both long and short septa. It bears, apparently, the closest resemblance to *Lithostrotion macouni* Lambe, from Fossil Point, Peace River, British Columbia (lat. 56° N., long. 123° W.), which also is characterized by small corallites. It is possible that Lambe's species on further study may be referred to the genus *Lithostrotionella*. There is a suggestion in the illustration of the transverse section that some of the septa do not extend to the theca. The chief differences between Lambe's species and *L. micra* would be in the greater number of septa in *L. micra*, and the presence of dissepiments in the intermediate septate zone as well as cystosepiments in the relatively wide peripheral zone, whereas Lambe states that in *L. macouni:*

> A narrow peripheral area formed of small upwardly and outwardly arching plates in one or two cycles surrounds a broad tabulate inner zone (Lambe, 1901, p. 176).

Shimer (1926, p. 29) collected some imperfectly preserved corals with small corallites in the Minnewanka area. He referred his specimens to *Lithostrotion* and mentioned that in his field notes he had referred to the species as *L. mamillare parvum*. He did not, however, publish a description under that name. Shimer's brief description could well apply to *Lithostrotionella micra*, and the Minnewanka and Mountain Park specimens may prove to be conspecific.

Horizon and locality.—The holotype was collected just below the summit of the northeast end of the spur east of the watershed of Rocky Pass, Mountain Park area, Alberta.

Holotype.—Canadian National Museum at Ottawa, Canada.

LITHOSTROTIONELLA sp.

Lithostrotion sp. GIRTY, *1899*. U. S. Geol. Survey Mon. 32, pt. 2, p. 513.

Girty (1899, p. 513) describes a prismatic form from the Madison limestone of Gallatin range and states:

> Transverse sections show that the whole interseptal space is more or less vesicular. Toward the periphery the vesicular tissue is coarse, stretching in extended loops, among which, in some individuals, the peripheral ends of the septa lose themselves.

The description quoted suggests that the unnamed species should be referred to the genus *Lithostrotionella*. The species is not referred to by Hayasaka (1936) in his paper on the North American species of *Lithostrotionella*.

Genus DIPHYPHYLLUM Lonsdale, 1845

The corallum consists of approximately parallel corallites characterized by short principal septa and the absence of a persistent columella. The genus is comparatively common in the upper Paleozoic Cordilleran faunas. The forms described below are, therefore, following Smith (1930, p. 180), not referred to *Lithostrotion* s.s., but to the genomorph, *Diphyphyllum*.

Occurrences of species of *Diphyphyllum*, as well as occurrences of those forms which have been referred to *Lithostrotion* sensu lato collected in the Cordilleran region are given in the list. It is very probable that detailed collections from the upper part of the Paleozoic section in the Cordilleran region of both the United States and Canada will increase the number of known species of *Diphyphyllum*. Close comparison of existing collections might indicate that some of the unidentified species are synonymous.

DIPHYPHYLLUM SINUOUSUM Kelly, n. name

Lithostrotion flexuosum WARREN, *1927*, Canada Geol. Survey Mem. 153, p. 47, pl. 3, fig. 7, pl. 6, fig. 2.

The name *Lithostrotion flexuosum* was used by Trautschold in 1879 (Hayasaka, 1937a), and I am therefore proposing, with Warren's approval, the name *sinuousum*, which, like *flexuosum* describes the bent corallites.

The writer has not had the opportunity of studying the holotype but has worked with material collected from the west slope of Tunnel Mountain, Banff area, Alberta, and very probably close to Warren's locality. The material collected by the writer agrees in most particulars with Warren's description. Polished and thin sections indicate that the principal septa have a length varying from one-half to three-quarters the radius of the corallite. In no instance did sections show septa extending as far axially as Warren indicates in his sketch (Warren, 1927, pl. 3, fig. 7). The columella does not show in all transverse sections, and although this may be the result of imperfect preservation, it may also indicate that the axial structure is not persistent. For these reasons the species is assigned to the genomorph *Diphyphyllum* rather than to *Lithostrotion*.

This coral has been described from the upper beds of the Rundle limestone on Tunnel Mountain, Banff area, Alberta. The age of the beds is doubtfully assigned to the Pennsylvanian by Warren. A form related to *L. sinuousum* is reported by Ross (1934, p. 979) from the Brazer of Idaho.

DIPHYPHYLLUM MUTABILE Kelly n. sp.
Plate 51, figs. 7, 8

Corallum large, at least 2 feet in diameter and 1 foot in height, composed of cylindrical corallites, subparallel to each other but with variable spacing. The crookedness of the corallites causes the distances between them to vary from less than 1 mm. to 6 mm.

Longitudinal section: Dissepiments usually in one series and confined to a narrow peripheral zone. About eight dissepiments occur in a vertical distance of 5 mm. The inner surface of each dissepiment is abruptly deflected adjacent to the outer border of the tabulate area. Tabulae occupy more than three-fourths the width of the corallite and are horizontal except for the abruptly depressed edges and a small central compressed conelike projection. There are about eight tabulae in a vertical distance of 5 mm. The columella is either present as a spine or is formed by the compressed portion of the central cone.

Transverse section: Corallites circular in outline, varying in diameter from 4 to 6.5 mm. There are about 24 principal septa, none of which extends more than one-half the way to the center. Minor septa alternate with the principal septa and are about two-thirds as long. A weak, imperfectly developed inner wall is formed along the inner

edge of the longer septa. This inner wall probably coincides with the depressed edges of the tabulae. Columella is visible only in sections through the conical projection in the center of the tabulae. Other transverse sections show distinct elliptical outlines where sections pass below the spine, or top of the conical projection.

Remarks.—This species resembles *Diphyphyllum sinuousum* Kelly in the general structure of the colony. It differs in its larger corallites and more numerous and relatively shorter septa. It bears a strong resemblance to the European form *Diphyphyllum phillipsi* (Milne Edwards and Haime), differing externally in the structure of the corallum, the North American forms having widely spaced corallites, while the European form has closely crowded corallites.

Horizon and localities.—Near the contact between the Rundle limestone and the Spray River shale from three localities in the Mountain Park area, Alberta. The holotype was collected on the southwest slope of the mountain northwest of the junction of McLeod River with Whitehorese Creek. The species was also collected on Blackface Creek about three-eighths mile above its junction with Rocky River. It is doubtfully identified from a single corallite collected on Lindsay Creek. The species is also present in a collection from the Brazer formation at Hannah Gulch, Montana, loaned through the courtesy of Dr. Charles Deiss.

Diphyphyllum sp.

A fragment of a corallum composed of closely crowded cylindrical corallites was found in an exposure of the Rundle formation on Blackface Creek. The speciman differs from *Diphyphyllum mutabile* in having somewhat fewer septa, there being about 20 principal and minor septa, and in showing marked discrepancy between the lengths of the principal and the minor septa. The minor septa of the unnamed species are quite inconspicuous and usually only about one-half as long as the principal septa.

OTHER FORMS OF LITHOSTROTIONTIDAE

In addition to the forms assigned by the writer to *Lithostrotionella* and *Diphyphyllum*, there are many references to occurrences of *Lithostrotion* in the Rocky Mountain sections. Several of the references are not accompanied by descriptions or figures, and it is not possible from the literature alone to determine whether the forms listed are massive or fasciculate. Other references (see table) to *Lithostrotion* suggest comparisons or relationships to European species but imply little more than an idea of external appearances. It is very likely that some of the forms, on restudy, may prove not to be *Lithostrotion* sensu stricto.

Genus Lithostrotion Fleming, 1828

The diagnosis of this genus by Lang and Smith (1935, p. 551) includes both massive and fasciculate coralla, in which the corallites possess a columella, long major septa, large tent-shaped tabulae supplemented by smaller horizontal tabulae near the edge of the tabulate zone, and dissepiments in the large forms of the genus.

Very few Cordilleran forms satisfy this definition, particularly if the term columella is interpreted strictly. It is evident from Smith's study (1920, p. 57) that he regards the columella of *Lithostrotion* as styliform and derived by the dilation of the counter septum. Such a definition excludes forms like *Lithostrotion proliferum* (see pl. 51, figs. 1, 4), which occurs in the Mississippi Valley region. This fact is pointed out by Ulrich (1905, see note accompanying pl. 3). For convenience a number of occurrences of *Lithostrotion* sensu lato are discussed below.

Lithostrotion whitneyi Meek, 1877

Plate 51, figures 2, 5

Lithostrotion whitneyi Meek, *1877*, Paleontology, U. S. Geol. Expl. 40th Parallel (King), vol. 4, p. 58, pl. 6, fig. 1, 1c.

Lithostrotion whitneyi, White, *1877*, U. S. Geog. Survey West 100th Mer. (Wheeler), vol. 4, pt. 1.

The species *L. whitneyi* was originally described from Boxelder Peak, Wasatch Range, Utah, but has been reported from a few other Rocky Mountain localities. Through the courtesy of Dr. J. Stewart Williams the author has had an opportunity of studying a specimen collected near Meek's locality. This specimen shows many small tabellae branching from the tent-shaped tabulae, which are continuously inclined from the center to the edge of the tabulate

area. The axial structure simulates a stylus, but a transverse section shows that the central portion is hollow, and that it is formed by the upraised tent-shaped tabulae rather than by the counter septum, which ends at the border of the conical portion of the upraised tabulae. In the relatively long principal septa, *L. whitneyi* suggests the genus *Lithostrotion* rather than *Diphyphyllum*. *L. whitneyi* may represent an evolutionary state intermediate between *Lithostrotion* sensu stricto and *Diphyphyllum*. The generic disposition of this species, is, in the present uncertainty, not changed. The figured specimens are in the collection of Utah State Agricultural College.

Shimer (1926, p. 26) has also reported *L. whitneyi* from the upper Rundle formation of the Lake Minnewanka area, which he has referred to the Pennsylvanian.

A specimen from the Brazer formation of Hannah Gulch, Montana, loaned through the courtesy of Dr. Charles Deiss, is very similar to *L. whitneyi*.

Ross (1934, pp. 981, 982) also cites this species in his discussion of the stratigraphy of southeastern Idaho.

White's specimens came from White Pine County, Nevada.

LITHOSTROTION HARMODITES Milne Edwards and Haime.

Lithostrotion harmodites MILNE EDWARDS AND HAIME, *1851*. Mon. des Polyp., Foss., vol. 5, p. 440, pl. 15, fig. 1, 1a.

Girty (in Mansfield 1927, p. 70) identified this form, with doubt, from the Brazer of southeastern Idaho. It is a fasciculate form and is regarded by Ulrich (1905, pl. 5, fig. 14) as a true member of the genus *Lithostrotion*.

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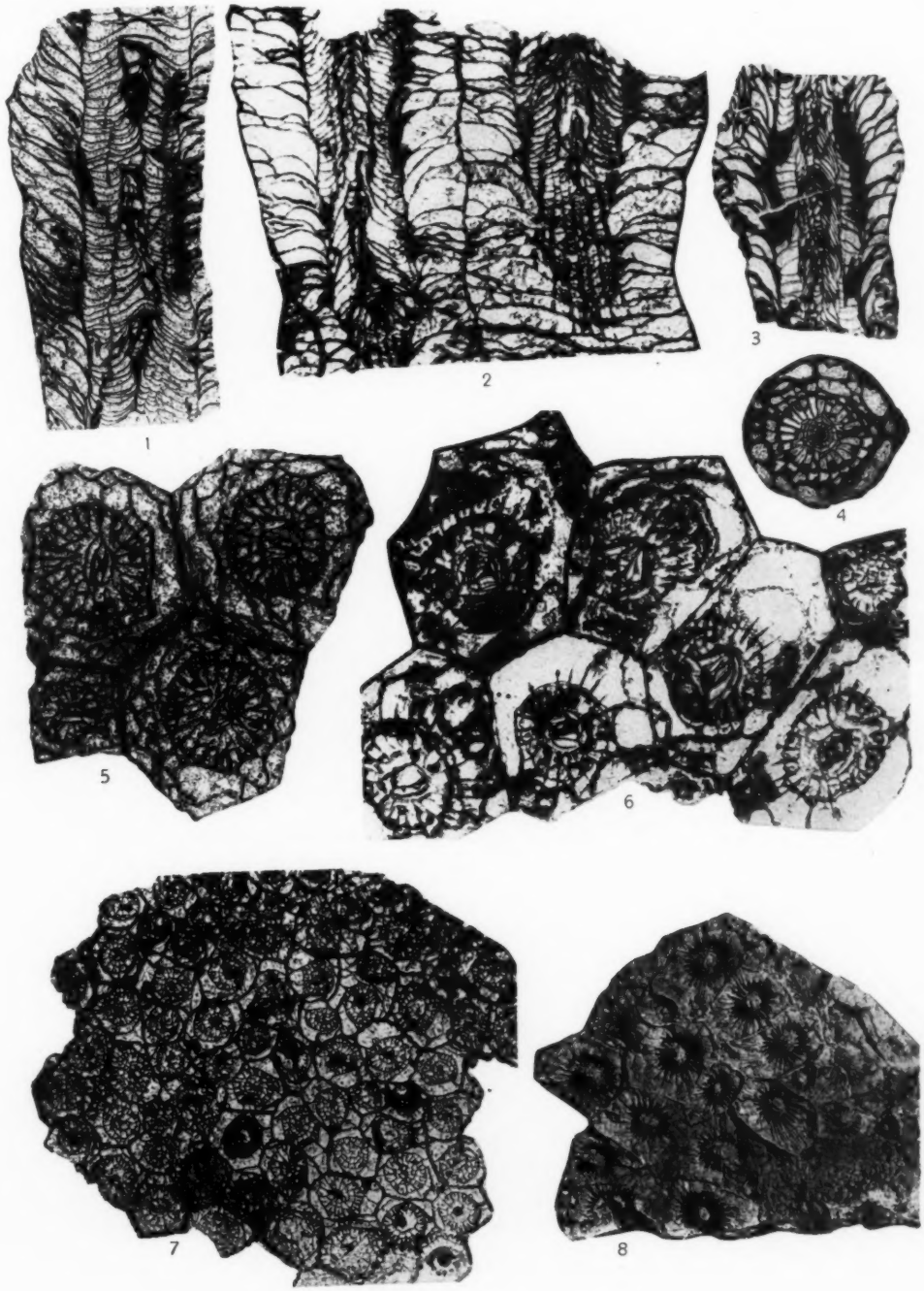
EXPLANATION OF PLATE 50

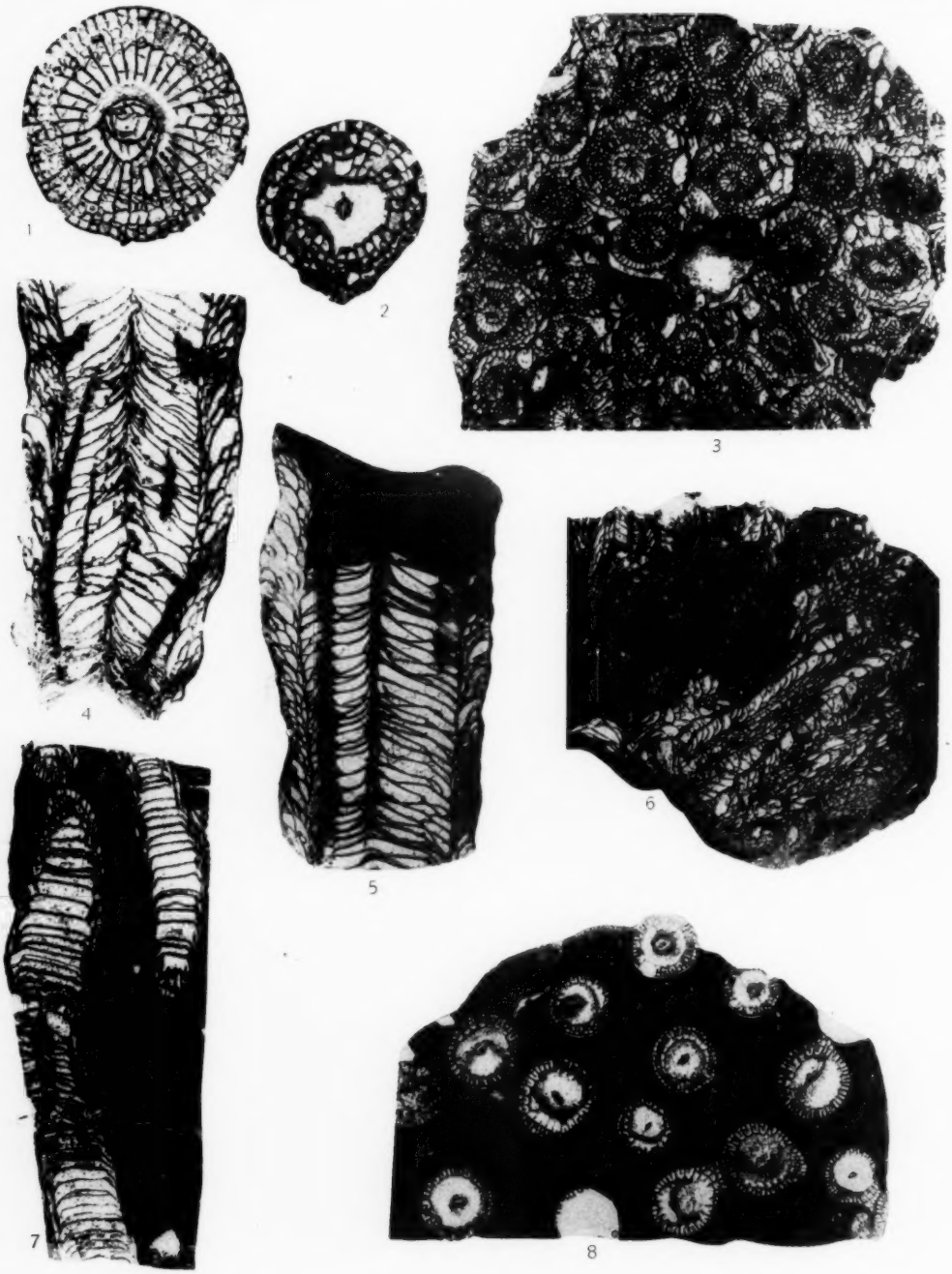
FIGS. *1, 2, 5, 6, 8—Lithostrotionella pennsylvanica* (Shimer). *1, 5*, Longitudinal and transverse sections of calcified specimen from Banff, Alberta, University of Michigan Museum of Paleontology. The longitudinal section illustrates the importance of the tabellae in the formation of the axial structure, and the transverse section shows the well-defined outer area of cystosepiments, ×2. *2, 6*, Transverse and longitudinal sections of silicified corallum from Bragg Creek area, Alberta, University of Michigan Museum of Paleontology no. 11049, ×2. *8*, *Lithostrotionella pennsylvanica* (Shimer), Bragg Creek area, Alberta, Michigan State College, collection no. 53xfl. Top view of exterior of corallum, ×2/3. (p. 352)

3, 4—Lonsdaleia duplicata (Martin), genotype and topotype, Corwen, North Wales, University of Michigan Museum of Paleontology no. 10329, ×1¼. *3*, Longitudinal section of corallite showing numerous inclined tabellae in central portion of tabularium. *4*, Transverse section of corallite illustrating outer vesiculated area, and reticulate pattern of axial structure formed by lamellae and inclined tabellae. (p. 351)

7—Lithostrotionella micra (Kelly) n. sp. Mountain Park area, Alberta, Canada Geol. Survey collection. Transverse section of corallum. Arrow points to row of three corallites which lack typical septal columella. ×2. (p. 357)



Kelly, Paleozoic Corals



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EXPLANATION OF PLATE 51

FIGS. *1, 4*—*Lithostrotion proliferum* Hall, Mill Springs, Kentucky, University of Michigan Museum of Paleontology, no. 21248, ×2. *1*, Transverse section illustrating the epitheca, as well as the absence of a septal columella, and suggesting characters of the genus *Thysanophyllum*. *4*, Longitudinal section illustrating the importance of upturned tabulae in the formation of the columella. (p. 359)

2, 5—*Lithostrotion whitneyi* Meek, near Boxelder Peak, Wasatch Range, Utah. Utah State College collection, ×2. *2*, Transverse section of single corallite showing lack of septal columella. *5*, Longitudinal section from same corallum. The tabulae are complex, and sharply upturned. The lower portion of the corallite reveals the lack of a septal columella. (p. 359)

3, 6—*Lithostrotionella jasperensis* Kelly, n. sp. Mountain Park area, Alberta. Canada Geol. Survey collection, ×2. *3*, Transverse section through corallum. The principal septa reach the center of the corallites, and the columella is formed by the fusion of the cardinal and counter septa in this species. *6*, Longitudinal section from same corallum as that figured above. The section passes through the columella of the first and of the third corallite counting from the left. The outer vesicular area is best illustrated in the inclined corallite near the right end of the section. (p. 356)

7, 8—*Diphyphyllum mutabile* Kelly, n. sp., Mountain Park area, Alberta. Canada Geol. Survey Collection, ×2. *7*, Longitudinal section through bent corallite shows flat tabulae away from center, and spinelike process where tabulae are sharply upturned. *8*, Transverse section illustrating common lack of a septal columella. The elliptical areas in the center are formed by transection of upturned tabulae. (p. 358)

JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 3, PP. 362–371, PLS. 52, 53, 4 TEXT FIGS., May 1942

ICHTHYOSAUR ROSTRA FROM CENTRAL CALIFORNIA

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THE two rostra of ichthyosaurs herewith described are enclosed in chert cobbles redeposited from the Franciscan into Quaternary gravels. The teeth resemble *Ichthyosaurus posthumus* from the Solnhofen, Tithonian (Portlandian) of Germany. The rostra resemble other specimens from the Upper Jurassic of Europe. There are also similarities to ichthyosaurs described from beds in Queensland which have been assigned to the Lower Cretaceous.

Assistance in the preparation of these materials was furnished by the personnel of the Work Projects Administration, Official Project No. 65-1-08-62, Unit A-1.

SYSTEMATIC DESCRIPTIONS

ICHTHYOSAURUS FRANCISCANUS
Camp, n. sp.
Plates 52, 53; text figures 1, 2A

Type.—A fragment of a rostrum (Univ. California Mus. Paleontology no. 33432) enclosed in a chert cobble (pl. 52).

Type locality.—Terrace gravel near the mouth of Corral Hollow Creek, 1 mile southeast of "Gravel Pit" (U.S.G.S. Carbona quadrangle), and 6 miles south of Tracy, San Joaquin County, Calif.; collected by Neal Johnstone Smith in the summer of 1935; Univ. California Mus. Paleontology loc. V3531.

Occurrence.—The loose gravel in which the specimen was found was presumably derived from the early Pleistocene Tulare formation. It contains numerous chert cobbles and pebbles similar to the one enclosing this specimen.

The cobble is water-worn. It is about 3½ inches in diameter and is smoothly rounded except on one side, where it has been roughly broken. Its reddish-brown weathered surface is slightly marred by flaked pits, gouges, and indistinct chatter marks. The polished cut surfaces are mottled greenish and reddish brown, and deep red around the bone.

A thin section of a chip was carefully examined by Dr. N. L. Taliaferro, who reports that the rock is:

> a red radiolarian chert identical with those so common in the Franciscan. This particular chert is identical with the cherts in the Franciscan [within five or six miles of the locality of occurrence] . . . many thin sections of which I have examined. The Radiolaria and the chert itself are completely recrystallized to a fine granular mosaic of quartz. . . . Minute granules and needles of zoisite and epidote are fairly abundant, . . . probably representing the recrystallization of small amounts of impurities originally present. The recrystallization shown by this chert could have been caused by deep burial under a thick prism of sediments such as actually accumulated in that particular region, or from heat developed from a nearby intrusive such as the ordinary serpentine or basalts of the Franciscan.

Two more thin sections were made and two broad surfaces of the hard nodule were polished to show cross sections of the snout. These were submitted to Dr. Arthur S. Campbell, who reports that only one determinable radiolarian was found:

> This is a *Dictyomitra* (*Nassellaria*), and possibly is *D. varians* Rüst, 1888, and occurs as a vertical section. The specimens are all much crowded together with spheroidal radiolarians (*Spumellaria*) but only "ghosts" of these are found, a large number of which are apparently of the discoidal type, but further determination appears impractical [pl. 53]. Hinde, 1894, found *Dictyomitra* in the radiolarian cherts from Buriburi Ridge [Franciscan] near San Mateo as well as a few other mostly indeterminate radiolarians.

All this points definitely to the Franciscan as the source of our specimen, and an accurate identification would be welcomed as a further contribution to the question of the age of the chert beds in this part of the Franciscan.

Description of type.—The rostral fragment extends through the center of the nodule and appeared on the surface in two abraded cross sections; these have now been polished to show the characters of the bone more clearly. The segment is about 2½ inches in length and represents that part of the rostrum at the extreme tips of the nasals and splenials. These bones appear only on the proximal end of the preserved fragment, except for the minute tip of one nasal, which

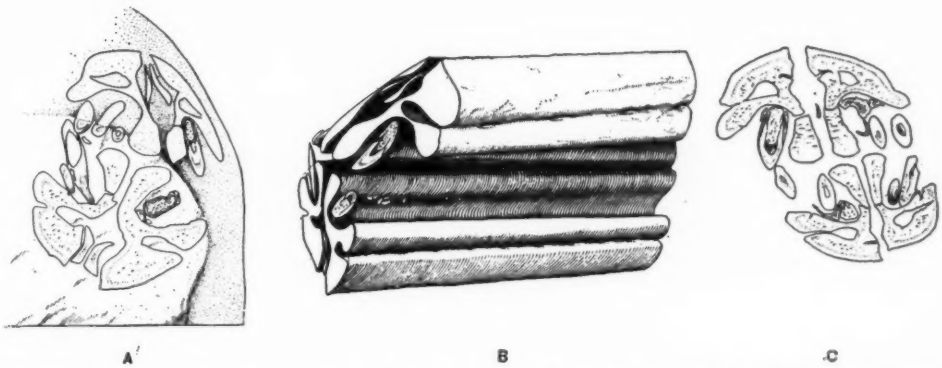

FIG. 1—*Ichthyosaurus franciscanus* Camp, n. sp. Type, ×⅔. A, Posterior end of section of upper and lower jaws. B, Rostral segment reconstructed from the cross sections, all but two teeth are omitted. C, Anterior end of section as shown on polished surface of matrix.

evidently extends into the anterior section. The section includes both the upper and lower jaws and several teeth.

The specimen is an ichthyosaur comparable with other specimens at hand and with many published figures and descriptions of rostral sections and teeth. Identification may be confirmed by noting the unusual similarity of the upper and lower jaws, the absence of a separate respiratory passage, the high palatal ridges on the dentaries, the position of the internal canals, and the structure of the teeth.

The present specimen, though at first sight inadequate for an exact identification, shows the following characters:

The teeth are numerous, closely set and crowded; on one oblique section three teeth appear in the same view (text fig. 1A); the faintly observable infolding at the base is covered with smooth cement, and obscure vertical striations appear on an impression of the tip of one of the crowns; the teeth are fairly small, simple, slightly curved cones, circular throughout in cross section; there are no carinae; the enamel is thin, not visible in the old teeth and is restricted to the tips of the tooth buds; the pulp cavities are large, hollow distally and are plugged with cement (text fig. 2A, pl. 53); the cement also extends around the base and halfway up the sides as a thin layer, which gradually diminishes and does not produce a swollen bulge below the crown. The teeth appear to have been loosely set in the connective tissue of the open dental groove, and the tooth buds lie at the inner margins of the bases of the old teeth. The largest exposed part of an upper tooth measures 13 mm. in height and 5 mm. in breadth. One of the lower teeth is 17.5 mm. in height and 4 mm. in breadth as sectioned. The rostrum, as reconstructed from the cross sections (text fig. 1B), was moderately stout and rather tapering.

This was not one of the slender-snouted ichthyosaurs, nor did it have a much abbreviated snout. The lower jaws in section were slightly smaller than the upper, but there is no marked discrepancy. Slight lon-

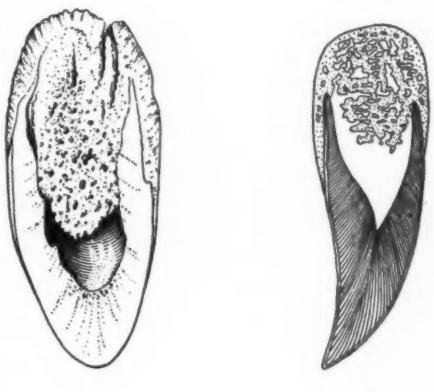

FIG. 2—A, *Ichthyosaurus franciscanus* Camp, n. sp. Longitudinal section of upper tooth of type, ×4. This tooth is also shown on plates 52 and 53. B, *Ichthyosaurus posthumus* Bauer, Longitudinal section of tooth, after Bauer (1898, pl. 26, fig. 27), from Solnhofen.

gitudinal grooves were present on the premaxillary and dentary bones, and these contained rather wide foramina, apparently well-spaced, horizontally elongated, and entering the internal canals. The internal canals for the vessels and nerves of the face are large compared with most other ichthyosaurs and become wider and funnellike toward the exterior. The horizontal diameter of the canals is somewhat exaggerated in text figure 1 because of the oblique planes of the sections. The internal canals run slightly external to the middle of the bases of the lingual ridges.

These ridges, developed as palatal extensions of the premaxillary bones and as median ridges of the dentaries, occlude on broadened surfaces, which act as buffers to prevent extreme interlocking and breakage of the teeth. The midsection of each ridge is broader than in some ichthyosaurs, and the ridges on the dentary bones are not so strongly curved as in some forms. The dental grooves, containing the teeth, are wider than in most of the known forms, and the premaxillary groove is shallow. This may be partly due to slight crushing, but it seems that the alveolar channel was exceptionally broad. The tips of the nasals are not deeply enclosed below the dorsal borders of the premaxillaries, and the extremities of the splenials are not so compressed as in some forms. These ventral bones are very doubtfully the angulars. In either case the splenials (or angulars) do not continue together so far forward as they do in *Ichthyosaurus communis* as figured by Sollas. Finally, the main mass of the premaxillary and dentary bones is thick and compact, without spongiosa, and the interspaces between these elements are not so wide as in some species (cf. Sollas, 1918, figs. 19, 20).

Comparisons.—Tooth characters of the present specimen should eliminate from consideration: (a) the primitive Triassic genera—*Mixosaurus*, *Shastasaurus*, and *Cymbospondylus*—in which the teeth have but little cement and are generally set in sockets; (b) the broad-finned ichthyosaurs allied to *Ichthyosaurus* (*Eurypterygius*) *communis*, in which the teeth are round, lack thickened cement, and are deeply and openly infolded at the base—most of these are Lower Liassic forms; (c) the small-toothed ichthyosaurs related to *I.* (*Stenopterygius*) *quadriscissus* of the Upper Lias, and *I.* (*Leptopterygius*) *tenuirostris* of the Upper and Lower Lias, in which the pulp cavities are relatively large, and the cement is thin or absent on the external walls of the teeth; (d) the forms with large teeth and those with compressed and carinated crowns, such as *I.* (*Leptopterygius*) *platyodon* from the Lower Lias and *I. trigonodon* from the Upper Lias; and (e) the Upper Jurassic and Cretaceous genera *Opthalmosaurus* and *Baptanodon*, in which the teeth are small and so loosely attached that they are frequently absent, especially in the front of the jaws, where the teeth are reduced and widely spaced, with secondary alveolar partitions.

Apatodonosaurus grayi Mehl (1928) is probably related to *Baptanodon*. The restoration of the "upper" dentition (Mehl's pl. 32, fig. 2) is subject to another interpretation than the one Mehl gives. If the fragment be regarded as part of the conjoined premaxillary and dentary, rather than as a segment of the two premaxillaries, the reconstruction becomes comparable with other sections of ichthyosaur snouts, and the teeth, instead of pointing inward toward the center of the mouth, come to be more normal in occlusion.

The various forms ascribed to *Ichthyosaurus campylodon* from the Lower Cretaceous of England, Russia, France, Germany and Italy, are fairly close to *franciscanus* in tooth structure, but the cement is thicker in *campylodon*, the base more bulbous, and the flutings on the base are usually coarser.

Comparison of rostral characters shows that the snout of *franciscanus* is not extremely short as in *I. brevirostris*, nor is it one of the delicate, slender-snouted forms such as *longirostris*, *tenuirostris*, and *quadriscissus*. In some of these (*Eurhinosaurus*), the lower jaws are much smaller and shorter than the upper. The presence of large internal canals in the premaxillaries and dentaries is characteristic of only a few of the known ichthyosaurs—notably *I. australis* as figured by Etheridge and by Longman, *I. longirostris?* as figured by Sollas, and *I. ceramensis* Martin. In Sollas' section of *longirostris?* (fig. 18), the lower jaws are larger than the upper, and the lingual flanges

of the dentary are more curved than in our specimen. In Martin's (1888, pl. 10, fig. 2) section of *ceramensis*, the premaxillary and dentary lingual flanges are very thin and delicate, and the teeth are openly fluted at the base.

A comparable section of the Russian Lower Cretaceous form of *Ichthyosaurus campylodon* as figured by Kiprijanoff (1881, pl. 9, fig. 8), shows that the tips of the nasals are transversely flattened and lie deeply buried beneath the premaxillaries, the tips of the splenials are thin vertical plates, the dentary alveolar channel is shallow, and teeth have bulbous, cement-covered "roots." Sections of the English form of *I. campylodon* given by Owen (1851, pl. 26) are similar to those given by Kiprijanoff. The Italian form of *campylodon* figured by Capellini (1890, pl. 1, fig. 5) has large, thick nasals, compressed splenials, and a large interspace between the dentaries. All this seems to exclude the campylodont forms of the European Lower Cretaceous.

Cornuel (1851a, figs. 1–3) describes a "gavial" from the Neocomian of Wassy in France that is certainly an ichthyosaur and is similar to ours except that there are no external premaxillary and dentary grooves, and the dentaries are slightly larger than the premaxillaries. Another similar form, apparently, is Cornuel's (1851b, figs. 1–4) second "gavial," from the Kimeridgian of Mussey. Here the lingual ridges of the dentary are high, thin, and rounded above, the preserved teeth are widely spaced and apparently have open roots and little or no cement. The internal canals of this form are large.

Ichthyosaurus hildesiensis Koken (1883, fig. 4), from the Neocomian of Germany, approaches *franciscanus* in the size of the internal canals, the height of the lingual ridges, and the presence of narrow longitudinal grooves. But a figured tooth of *I. hildesiensis* is about 70 mm. in height and has a bulbous base. A supposedly similar form, *I. steleodon*, described from the Neocomian of the Volga by Bogolubow (1909, pl. 2, figs. 6, 7), has anterior teeth 55 mm. in height, narrow and closely set. The dentary lingual ridges are higher than those on the premaxillaries. *I. strombecki* von Meyer, from the Lower Cretaceous of Germany, may seem to be a related form. It has crowded teeth only 20–25 mm. in length without bulbous bases and with smooth cement and apparently with shaded bands on the neck. There are deep lateral grooves on the premaxillaries and dentaries. But a cross section at the anterior end of the splenials (Meyer, 1862, pl. 11, fig. 2) shows these bones to be compressed as in *I. campylodon*.

Ichthyosaurus platydactylus Broili, 1907, from the Aptian of Hannover, cannot be accurately compared. The only tooth present has been displaced and is fragmentary. It is described as cylindrical and furrowed. The snout is tapering, not greatly elongated, and there is a lateral groove in the premaxillary.

Ichthyosaurus acutirostris Fraas (1913, pl. 2, fig. 4), from the Upper Lias of Holzmaden, is similar to *franciscanus* in the cross section of the snout. The splenials are obtuse, not compressed, at their tips. The lower jaws are slightly smaller than the upper, the internal canals are large, and the external furrows are weak. The teeth are moderate in size and closely set but differ from *franciscanus* in having anterior and posterior carinae.

I. bambergensis, described by Franz Bauer (1901, pp. 12–13) from the Upper Lias of Geisfeld, has teeth 12 mm. in length, conical, round at the point, compressed at base, and barely curved. The crowns are apparently smooth, the roots irregularly folded. The pulp cavity reaches very high—nearly to the apex. The extent of the pulp recalls the Swabian ichthyosaurs (*I. quadriscissus* and *crassicostatus*) in which, according to Fraas (1891, pl. 1, figs. 9, 10), the pulp cavity is only partly filled with cement. In *bambergensis*, the cement nearly fills the pulp cavity.

I. leptospondylus von Meyer (1863, pl. 23) comes from the lithographic Upper Jurassic beds of Eichstätt. The premaxillaries are broad and shallow. The dental grooves are broad, and the lingual ridges are stout, as in *franciscanus*. The teeth, at least anteriorly, have finely furrowed bases lightly coated with cement. Fraas (1891, pl. 11, fig. 22) gives a longitudinal section of a tooth of *leptospondylus*. The cement encircling the base is very thin, and there is no plug of cement in the open pulp cavity. Except for

this, the specimens are very similar.

In his original description of *I. posthumus*, Wagner (1852, pl. 20, figs. 4, 5) figures the type tooth of this species. It is only slightly bulbous at the base, with smooth cement, an internal excavation for the replacing bud, and delicate striae on the crown. The tooth is inwardly curved, and the neck shows two shaded "color" bands. Lydekker, 1888, in the British Museum Catalogue (vol. 2, fig. 12) refers *posthumus* to Owen's *I. trigonus* and figures a tooth referred to the latter, which has a bulbous base, with slightly visible furrows; and the striae on the crown reach the base and are not separated from it by light and dark bands. *I. trigonus* is from the Kimeridgian of England, and *posthumus* occurs in the lithographic beds of Bavaria, a somewhat higher horizon.

"*Ichthyosaurus trigonus* var *posthumus*" from the Upper Jurassic (Tithonian) Solnhofen, has been studied by Franz Bauer (1898, pl. 28, fig. 27). The referred tooth in longitudinal section is so similar to *franciscanus* that I copy it for comparison (text fig. 2B) The spongy cement covering the base and entering the pulp cavity is similar in the two specimens.

Bauer (pl. 25, fig. 1) figures the premaxillary of another specimen of *posthumus* from Oberndorff. In this the lateral groove is faint and the foramina are conspicuous and elongated. The lingual ridge is slightly excavated from the teeth and extends well below the level of the outer border of the premaxillary. Unfortunately, a cross section is not given, but from the structure of the teeth and what is known of the premaxillary, the species (or variety) *posthumus* appears to be closer to *franciscanus* than are other described European forms.

Ichthyosaurs from undoubted Jurassic beds of the western Pacific region are unknown. Some of those in Queensland assigned to the Lower Cretaceous resemble *franciscanus* in details of the cross section of the snout. The best preserved specimen is *Ichthyosaurus "australis,"* described by Longman (1922, fig. 2). Here the lower and upper jaws are nearly the same size; the internal canals are large; the external furrows are weak, and the lateral foramina are prominent; the lingual ridges are shaped as in our specimen, and the dental grooves are wide. The teeth in Longman's specimen are poorly preserved. They are said to be evenly conical without markedly bulbous bases and without carinae. The crowns are striated. They are about 55 mm. in length in the mid-region of the snout and longitudinally striated but without visibly furrowed roots. Smooth cement is evidently present around the base.

Etheridge (1888) has described and figured some earlier remains of *I. "australis,"* for which he proposed the name *I. marathonensis*. The cross section he figures (pl. 7) is so similar to Longman's specimen of *"australis"* that further comment is unnecessary. It is significant in that the teeth shown are similar to ours in having a cement plug at the base and weak cement-covered furrows around the bases. These anterior teeth are about 30 mm. in height. The bases of the teeth do not seem to be expanded, and the dental channel is high as in *franciscanus*. There appears to be an excavated articular surface on the dentary for a round-tipped splenial.

McCoy (1868) in describing the original material of *australis*, stated that:

> the teeth have a rough, bony, square base, like those of the *I. campylodon* from the Lower Chalk of Cambridge, above which the smooth base of the crown has a circular section; the rest of the conical crown being longitudinally marked with close irregular, obtuse ridges.

Unless this description is wrong, it appears that the teeth of McCoy's type specimen of *australis* more closely resemble *I. campylodon* than does *franciscanus*. The separation of the crown from the base by smooth enamel, however, is a character shown by the type tooth of *I. posthumus*.

Mention should be made of *Tangaroasaurus kakanuiensis* recently described by Benham (1935) from marine mid-Tertiary beds of New Zealand. The author inclines to the view that this jaw is an ichthyosaurid reptile. It differs from ichthyosaurs and other reptiles, however, in the presence of closed roots on the teeth. The dental lingual ridges are massive, and the internal canals are enclosed within their bases. The teeth have spiked carinae and are mostly set in sockets. This specimen is evidently a squalodont cetacean. A cast of a tooth kindly sent by Sir William Benham confirms this, and Dr.

Remington Kellogg believes the form to be a squalodont of an unidentified type.

ICHTHYOSAURUS CALIFORNICUS
Camp, n. sp.
Text figures 3, 4

Type.—A fragment of a rostrum (Univ. California Mus. Paleontology, no. 36,394) in a matrix of radiolarian chert (fig. 3).

FIG. 3—*Ichthyosaurus californicus* Camp, n. sp. Type, ×1. Section of rostrum with five teeth.

Type locality.—Quaternary stream gravels near the mouth of Puerto Canyon (U.S.G.S. Orestimba quadrangle), about five miles west of Patterson, Stanislaus County, Calif., collected by John Hammond in 1940; Univ. California Mus. Paleontology, loc. no. V 4041; received by exchange, through Mr. Hugo Goeritz. This place is about 20 miles south of the type locality of *I. franciscanus.*

Occurrence.—The specimen consists almost entirely of the conjoined premaxillaries and dentaries with six visible teeth on one side. The upper parts of the premaxillaries are worn away, exposing the bases of the teeth. A lateral view of the tooth row appears on the left side. The specimen has been crushed and deformed by compression, and the bone is intersected by branching veins of crystalline quartz. Except for these veins, the bone is somewhat harder than the matrix, which has largely been removed, presumably by stream-channel abrasion.

The residual patches of matrix appear to be very similar to the matrix of *I. franciscanus.* A thin envelope of deep red chert surrounds the bone, just as in *franciscanus.* This passes abruptly into greenish and brownish chert, which evidently formed the mass of the original nodule. Radiolarian "ghosts" are numerous and are of the same size and shape as in the matrix of *franciscanus.* A superficial examination is enough to convince Dr. Taliaferro of the Franciscan source of this specimen.

There is evidence, therefore, that this specimen also has been derived from Fran-

ciscan cherts, which are abundant nearby, in the central Coast Ranges.

Description of type.—The rostral fragment was sawn in two along the axis of one of the upper teeth. The polished surface of this cut reveals an entire section of the lower jaws near the anterior extremities of the splenials. The section (fig. 4 B), which is comparable with that of *I. franciscanus* (fig. 1A), represents a rostrum of about two and one half times the lineal dimensions of *franciscanus*. There are some other differences, notably the large size of the lateral furrows in *californicus*, and the more elongated expanded ends of the lingual ridges. The teeth are of course much larger (40 mm. in length) and have very thin cement externally around their bases. There are at present no visible striations on the crowns of these teeth—but this may be due to abrasion or alteration of the enamel. An enamel cap (fig. 4A) is clearly visible over the entire crown of one of the tooth buds. A large adjacent tooth displays only a small area of enamel near the apex of the crown. No histological details appear to be preserved. The teeth are fairly widely spaced.

Otherwise *californicus* is similar to *franciscanus*. The internal dentary canals are large; the tips of the splenials are blunt and curve around the bases of the dentaries; the dental channel containing the teeth is broad; the teeth are simple cones, without carinae and without expanded bases; the pulp cavities are hollow except for a plug of cement. The bases of the older teeth are fluted, and the flutings are smoothly covered with thin cement (fig. 4A).

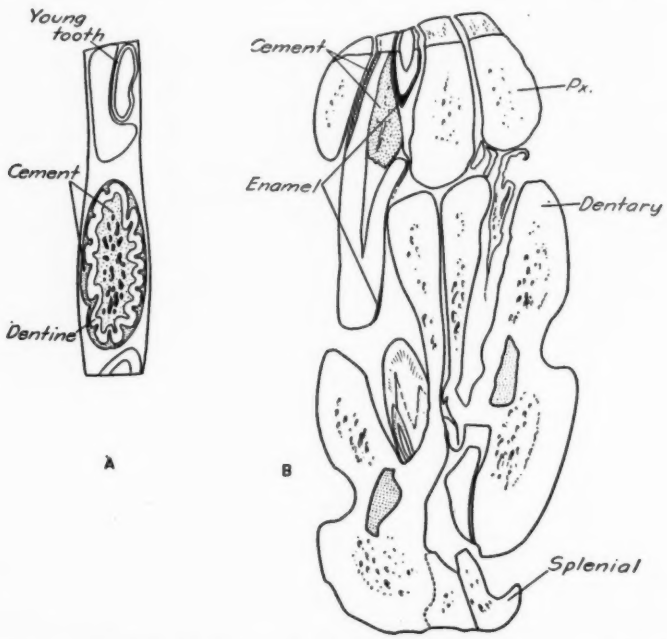

FIG. 4—*Ichthyosaurus californicus* Camp, n. sp. Type, ×1. A, Cross-section of base of upper tooth, showing cement-covered folded dentine and cement in pulp cavity. Flattening is due to compression in the matrix. B, Oblique section of snout, deformed by pressure, showing enamel cap on young tooth and patch of enamel on crown of old tooth.

Comparisons.—The only previously described ichthyosaur rostrum that appears to be strictly comparable with *californicus* is a fragmentary specimen of uncertain age and occurrence, from Bedeille, France, described by Pouech (1882, pl. 5, figs. 1–5), who gives cross sections. Astre (1931) has restudied the occurrence and believes it to have been a redeposition in Cenomanian beds from an earlier horizon, "probably Jurassic" in age.

Ichthyosaurus franciscanus Camp, n. sp.
Type, × 1

Ichthyosaurus franciscanus Camp, n. sp.

Type, × 6. Detail of right premaxillary and tooth. "Ghosts" of radiolarians are numerous in the space between the premaxillaries.

The specimen is a section of the lower jaws with parts of the upper dentition and the tips of the premaxillary lingual ridges. The dentary is deeply furrowed laterally as in *californicus*, the internal canals are large, with wide external openings. The shape of the lingual ridges is similar to *californicus*, and the tips of the splenials are rounded. The teeth are large, with striated crowns and smooth, tapering bases, apparently thinly covered with cement. There appears to be a smooth interval at the neck, as in *posthumus*.

REVIEW OF CHARACTERS SHOWN BY THE FRANCISCAN SPECIMENS

Important characters used in the classification of the ichthyosaurs, including those of the pelvis, paddles, ribs, and vertebrae, are not available in our Franciscan material. The ichthyosaur skull, as in other marine reptiles, is relatively conservative. Tooth characters apparently show some progressively modified features. The Triassic genera *Mixosaurus* and *Cymbospondylus* are thecodont, *Shastasaurus* is subthecodont with thin, transverse alveolar walls between some of the teeth. *Merriamia* is the only known Triassic form without complete alveolar walls. Little or no cement is present in the Triassic forms.

In many of the early ichthyosaurs, as late as the Middle Jurassic, the teeth have not yet reached a stage where much cement is laid down around the outer wall of the base. In such species as *communis*, *breviceps*, and *intermedius*, from the Lias, the teeth lack cement and are strongly fluted at their bases. In the Holzmaden species, the teeth tend to be small, needlelike, with large pulp cavities, and either openly fluted or covered with a thin layer of basal cement. In the so-called platyodont ichthyosaurs of the European Lias, the teeth are either openly fluted at the base, or they develop compressed carinated crowns with cement around the base.

The numerous campylodont forms of the Cretaceous are preceded in the Upper Jurassic by such species as *trigonus*, *leptospondylus*, *entheciodon* and *posthumus*, in which the cement buries the folds on the bases of the teeth but is not always thick enough to form a bulbous base. *Posthumus* and *leptospondylus* are much alike except that the former has a plug of cement in the open base of the tooth. The tooth of *I. quadriscissus* is also set on a plug of cement, but in this species the cement does not extend up around the "root," and the pulp cavity reaches nearly to the apex.

The Cretaceous ichthyosaurs belong to two main groups. In one of these, represented by *Baptanodon* and *Ophthalmosaurus*, the teeth are much reduced both in size and number and are very loosely set in the connective tissue of the dental groove. In the other group, the campylodont ichthyosaurs, the bases of the teeth are bulbous, with very thick cement, and the flutings are entirely concealed by the cement. Sometimes the base of the tooth tends to become squarish or angulated. The striae on the crowns usually reach the neck of the tooth.

AGE DETERMINATIONS

Ichthyosaurs range from the Middle and Upper Triassic of Europe, Spitzbergen, Western North America and the East Indies, through the entire marine Jurassic of Europe, the Middle and Upper Jurassic of Wyoming, and into the Lower Cretaceous of Europe, Greenland (?), La Plata, Argentina, Chile, India, Ceram (?), New Zealand (?), and Queensland. The last appearance seems to be in the Upper Cretaceous (Benton) of North America, if we may discard a dubious record from the Upper Chalk of England.

At least three alleged cases of secondary deposition in late Cretaceous and post-Cretaceous deposits have been previously recorded; one in France, another in Italy, and a third in Malta. The first two specimens are small sections of snout.

The two ichthyosaur rostra herewith described from the Franciscan group are the only vertebrate remains yet recovered from that complex series of rocks. The Franciscan is notoriously barren except for unidentified carbonized plant fragments and countless poorly preserved radiolarians entombed in the chert lenses. The best known molluscan fauna east of San Luis Obispo is considered to be Tithonian. At this locality, the beds containing this fauna are overlain, on a widespread angular discordance of 15°, by a basal conglomerate, which may be in the Lower Knoxville (Jurassic).

The Franciscan lies below beds that are doubtfully regarded as Lower Cretaceous (Upper Knoxville) in age. Its base is apparently not exposed throughout its extensive area. Its upper limits are also uncertain. There is doubt as to the age of the entire series and still more uncertainty concerning the varied and often highly deformed rock members.

Ichthyosaur remains such as these provide somewhat insecure evidence upon which to base a precise age determination, as some of the Upper Jurassic forms continue into the Lower Cretaceous. So far as may now be determined, the Franciscan species *franciscanus* shows closest resemblances, in details of tooth structure, to *Ichthyosaurus posthumus* from the Tithonian (Portlandian) lithographic beds of Solnhofen. A few other Upper Jurassic and Lower Cretaceous European forms seem to be closely related as well as that form (*marathonensis*) of *Ichthyosaurus "australis"* described by Etheridge and by Longman from Queensland. This occurs in the Rolling Downs "formation" now assigned by some of the Australian paleontologists to the Lower Cretaceous, but a part of that series may prove to be Jurassic in age.

The difference between the type material of *I. australis* and the specimens later described by Etheridge and by Longman suggests that there may actually be two kinds of ichthyosaurs represented in the Rolling Downs formation, as Etheridge suspected. It may also reopen the old question as to the presence in the Rolling Downs of some rocks possibly Upper Jurassic in age. But the differences in the ichthyosaurs are not great and may not be significant. Dr. S. P. Welles, who has studied the descriptions of the plesiosaurs from New Zealand and Australia, concludes that those from New Zealand and South Australia (*Cimoliasaurus leucoscopelus, C. maccoyi, Mauisaurus haastii, Plesiosaurus australis = P. crassicostatus = P. mackayii = ?P. traversii*) resemble northern Upper Cretaceous forms. The Queensland plesiosaurs are all said to occur in the Rolling Downs formation. Of these, the gigantic *Kronosaurus* is considered to be a Lower Cretaceous pliosaur. *Plesiosaurus macrospondylus* is "large in comparison with the Liassic forms and small for the Cretaceous." Other vertebrae from the Walsh and Flinders Rivers, including *P. sutherlandi*, can be regarded as Lower Cretaceous forms.

Jack and Etheridge in their "Geology of Queensland" give detailed lists of the abundant invertebrate fossils from the Rolling Downs. The prevalent opinion is that these are Lower Cretaceous in age, "admitting, however, that they contain an admixture of Oolitic life." The sequence is: Ipswich (Upper Trias-Jurassic), Rolling Downs (Lower Cretaceous) and Desert Sandstone (Upper Cretaceous). "To draw a definite line between the Ipswich and the Rolling Downs is quite impracticable. The appearance of Belemnites and Ammonites generally marks the transition," from the lower plant-bearing beds.

The Rolling Downs beds, of great thickness, are exposed as over a vast area of plains, and separation into units has been indefinite. Early work indicated that the Marathon beds, in which Etheridge's type of *Ichthyosaurus marathonensis* was found, are high in the section. But Etheridge's later opinion (1892) was that the Hughenden, Marathon and Wollumbilla beds are on practically the same horizon.

Walkom (1919), working with plants, assigns the Burrum beds, which overlie at least a part of the marine series, to the lowest divisions of the European Cretaceous. He adds:

> It certainly looks as if the Rolling Downs series may have to be regarded as Upper Jurassic.

David (1932), in a general review of Australian stratigraphy, places the Burrum between the lower, cold-water marine beds (the Roma series), which he regards as Aptian, and the upper, warm-water marine series (the Tambo), which he places in the Upper Albian. This upper series is said to contain large ammonites, *Hamites, Labeceras* and *Myloceras*, as well as the ichthyosaurs and plesiosaurs. This division is accepted by Longman (1935).

Our second species *californicus*, is matched closely by a presumably redeposited fragment of uncertain age, supposedly from Upper Jurassic beds, in France. The two Franciscan species appear to be related. The smaller form (*franciscanus*) is evidently not a young individual of the larger because

franciscanus has relatively thicker cement around the bases of the teeth.

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CARBONIFEROUS AND PERMIAN CORALS FROM CENTRAL OREGON

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ABSTRACT—A small area in Crook County, Oregon, has yielded one new species of *Dibunophyllum*, two of *Waagenophyllum*, four of *Lithostrotion* (representing three subgenera), one of *Campophyllum?*, and several unnamed corals.

HIGHLY folded Carboniferous and Permian strata occupying a small area 15 miles southeast of Paulina, Crook County, Oregon have yielded several genera of rugose corals. Most of the forms described herein show closer affinity to Eurasian species than to known species of the Western Hemisphere. The localities from which the corals were obtained lie in the upper drainage of Crooked River, near the headwaters of two tributaries known as Twelvemile and Grindstone Creeks. Wade Butte on the southern margin of the Dayville quadrangle is 1 mile northwest of the nearest Paleozoic exposure.

Upper Paleozoic strata were recognized in this region by Washburne (1903) and by E. L. Packard (1928, 1932). Upon invitation of Dr. Packard the area was visited by the writer during the summer of 1937. Later field work by S. A. Berthiaume and the writer led to preparation of a report on Paleozoic stratigraphy, which will constitute a separate paper.

Berthiaume and the writer have recognized three Paleozoic formations ranging in age from Lower Carboniferous (about Viséan) to Permian. Triassic beds overlie the Permian. The sequence is as follows:

Section 15 miles southeast of Paulina, Ore.

	Feet
Triassic: Sandstones and conglomerates	3500–4000
Unconformity.	
Permian, Coyote Butte formation: Fusulinid limestones (*Parafusulina*, *Schwagerina*), sandy limestones and sandstones	900
Local angular discordance.	
Pennsylvanian, Spotted Ridge formation: Coarse conglomerate, carbonaceous sandstone and indurated mudstone, bedded cherts; in part terrestrial with Pennsylvanian flora (Read and Merriam, 1940)	1000–1500
Disconformity.	
Lower Carboniferous, Coffee Creek formation: Marine limestones and sandstones, with *Gigantella*, *Striatifera* and *Dibunophyllum*	900–1000

Stratigraphic studies in the Paleozoics of this region are greatly complicated by facies change, pinching out of members, and disturbance of the beds. Precise location of the corals according to horizon has therefore not been practicable. However, nearly all the Carboniferous corals were found in association with a diagnostic brachiopod fauna. The greater part of the Permian forms occur within or adjacent to horizons bearing Permian fusulinids and brachiopods. No corals have been found in the partly marine Spotted Ridge Pennsylvanian.

The writer wishes to thank Dr. Earl L. Packard for support given by him in furtherance of work under this project. Grateful acknowledgement is made Dr. G. A. Cooper for identification of brachiopod species and to Dr. L. G. Henbest and Dr. S. A. Berthiaume for determination of fusulinid genera. Field work leading to this and forthcoming reports dealing with the same area has in part been made possible by a grant from the Trustee-Faculty Research Committee of Cornell University.

SYSTEMATIC DESCRIPTIONS[1]

Genus DIBUNOPHYLLUM Nicholson and Thomson

Genolectotype (Gregory, 1917, p. 232), *Dibunophyllum muirheadi* Nicholson and Thomson (see Hill, 1938, p. 65).

A critical revision of British *Dibunophyllum* species has recently been published by

[1] Terminology used in description follows that employed by Smith (1935) and by Hill (1935). See also Sanford (1939).

Hill (Hill, 1938, p. 65), who notes that the genus is characteristic of the Upper Viséan, and Lower Namurian of the British Isles, Belgium, France, Russia, Novaya Zemlya, the western Sahara, and eastern Canada. In China several Lower Carboniferous species have been referred to this genus by Yu (1933, p. 124). *Dibunophyllum* has been recorded in the Middle Carboniferous of China and Czechoslovakia as well as in the Upper Carboniferous of the Carnic Alps. At least two species from the Permian of China have been placed in *Dibunophyllum* (Huang, 1932, pp. 47–48). The genus *Dibunophyllum* appears to be most characteristic of the *Dibunophyllum* zone in the British Isles (middle to upper Viséan) but persists to the end of coral zone 4 of Hill (1938, pp. 17, 66) which is presumably lower Namurian or early Upper Carboniferous. In America records of *Dibunophyllum* are extremely scanty. One species, *D. lambii* Bell, occurs in the Horton-Windsor district, Nova Scotia, in the upper Windsor, which is regarded by Bell (1929; Lewis, 1935) as upper Viséan. Another form, *D. valeriae* Newell, occurs in the Pennsylvanian Eudora shale of Kansas. The Oregon occurrence is thus of particular interest in point of distribution. Though the entire fauna associated with *Dibunophyllum* at the Oregon localities has not been completely analyzed, it is known to include such genera as *Gigantella* and *Striatifera*, which, together with *Dibunophyllum*, lend support to a Viséan age for these deposits.

DIBUNOPHYLLUM OREGONENSIS
Merriam, n. sp.
Plate 54, figures 1–13; plate 55, figure 4

Holotype, Cornell Univ. no. 38,692.

Corallum simple, becoming cylindrical when mature, attaining a diameter of 28 mm. Septa number as high as 78 (inclusive of minor septa). Major septa strongly thickened for the greater part of their length but usually attenuated peripherally. Minor septa thin and irregular to obscure or withdrawn close to periphery. Attenuated continuations of major septa may reach the central column, but thickening or dilation of major septa almost always stops short of the column. Dissepimental zone often broad; dissepiments with herringbone pattern. Axial structure ovoidal, compact, and from slightly less than one-third to greater than one-third of diameter of corallum; medial plate normally straight, continuous, and thickened in varying degree. Dissepiments small. Tabulae inclined toward periphery; inclination usually gentle, rarely more than 35°. Individual tabulae occasionally traceable from dissepimentarium to central column. Tabellae steeply inclined, numerous, often crowded.

Remarks.—Dibunophyllum oregonensis shows great variation with respect to the axial structure within the same local assemblage. Individuals from different localities show much variation as to maximum size of mature individuals as well as features of the interior. In a few instances the medial plate is aborted or unrecognizable. Certain individuals show an unusually large dense central column, which recalls that of the genus *Aulophyllum*, but, unlike *Aulophyllum*, usually retain at least a trace of the medial plate. In other variants the major septa and the medial plate are greatly thickened.

Affinities.—Dibunophyllum oregonensis resembles *D. bipartitum* (McCoy) from the Lower Carboniferous (Viséan) of Great Britain but differs from the British form in having a much smaller number of major septa, better developed minor septa, the dilated inner portions of the major septa longer, and on the whole a somewhat narrower dissepimental zone. In general the thickening of major septa in *oregonensis* is carried to a greater degree than in *bipartitum*. Of the various species of *Dibunophyllum* and related types described from the Lower Carboniferous of China by Yu (1933) none would appear to be closely related to the Oregon form, though there are resemblances in the variable axial columns.

Occurrence.—Lower Carboniferous, Coffee Creek formation. Locality S 2 (type locality), larger individuals common. Associated with *Lithostrotion* (*Siphonodendron*) *oregonensis*, *Campophyllum? readi*, *Gigantella* sp., *Striatifera* sp. Locality S 62, small type common; associated with *Gigantella* and *Striatifera*.

Genus WAAGENOPHYLLUM
Hayasaka

Genotype, *Lonsdaleia indica* (Waagen and

Wentzel) (see Grabau, 1931; Huang, 1932; Smith, 1935).

The generic name was proposed by Hayasaka (1924, p. 23) to replace *Waagenella* Yabe and Hayasaka (1915), which is preoccupied. The diagnosis given by Smith (1935, p. 33) is as follows:

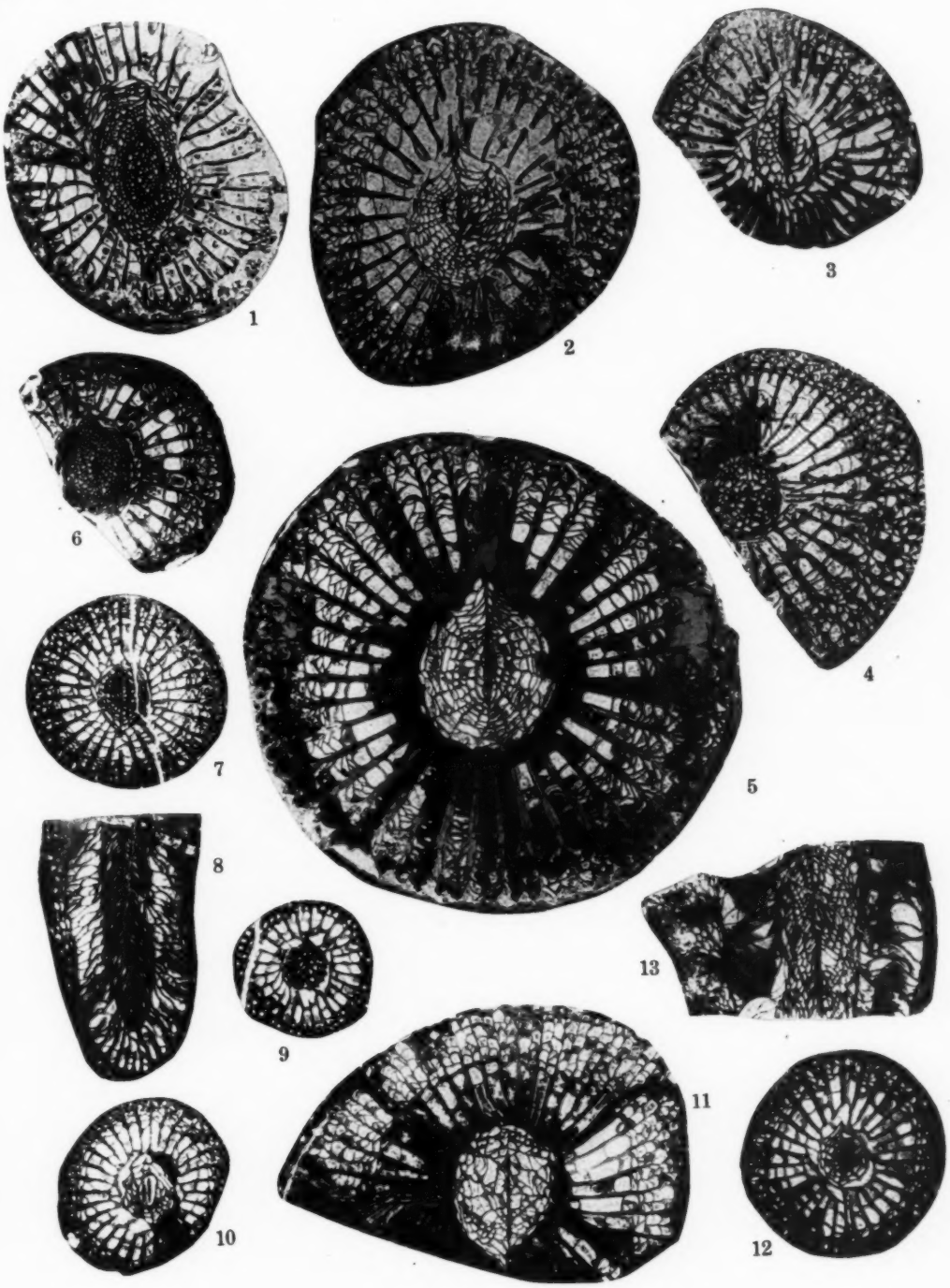
> Phaceloid and cerioid rugose corals with typically a clisiophylloid axial column which almost fills the tabularium, more or less horizontal tabulae sometimes suppressed, large steeply inclined dissepiments, and septa which reach the epitheca and are united at their peripheral edges by stereome to form a narrow stereozone. Germination is non-parricidal.

As noted by Smith this diagnosis applies particularly to the genotype; other species such as *Waagenophyllum columbicum* Smith (1935, p. 38) differ in several important details. For example some individuals of the American type (Smith, 1935, pl. 9, fig. 7) show a broad tabular zone, and the dissepiments do not agree well with those of the type. As might be expected the Oregon forms referred to this genus resemble the British Columbian type, which is referred to *Waagenophyllum* by Smith with the remark that *W. columbicum* is not a typical member of the genus. At present the genus *Waagenophyllum* is interpreted broadly. Among the Oregon forms, occasional individuals show narrow tabulae with the axial column almost touching the dissepimentarium and exhibit large very steeply inclined dissepiments; however, specimens which more nearly conform to the generic diagnosis appear to be in the minority. The characters of the genus *Corwenia* Smith and Ryder (1926) from the Lower Carboniferous of Great Britain approach those of the Permian *Waagenophyllum*. However, *Corwenia* shows a wide zone of tabulae around the axial column, usually includes individuals with a more loosely formed central column, and possesses only small dissepiments. The relationship of *Corwenia* to *Waagenophyllum* will probably become better understood with further study of these Rugosa. As remarked by Hill (1938, p. 100), certain Asiatic species that have been referred to *Corwenia* are probably more closely related to *Waagenophyllum*. Though the American forms show a similarity to *Corwenia* and their generic position has not been fully established, they seem for the present to fit best in *Waagenophyllum*.

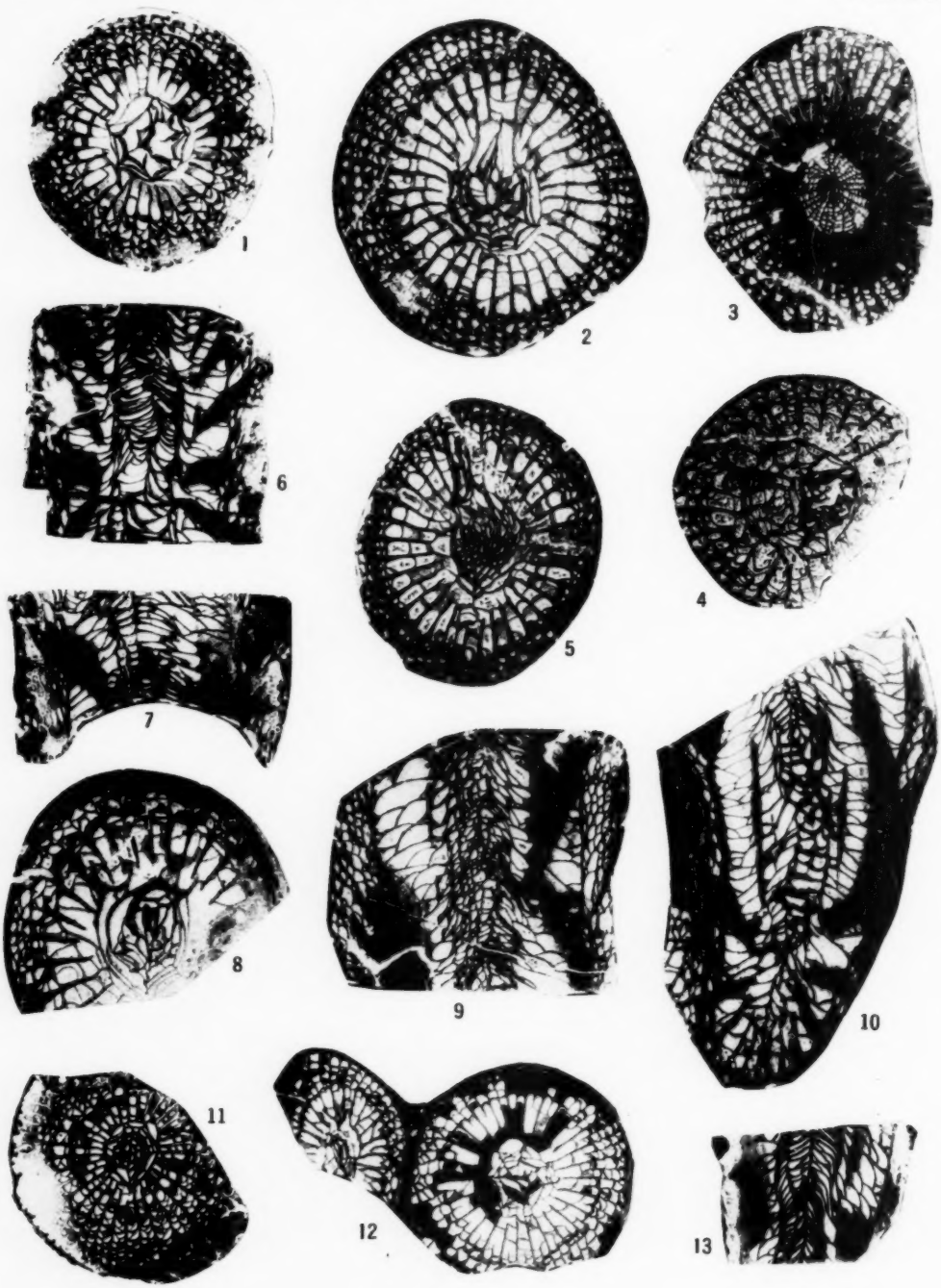
Waagenophyllum as recognized by Smith (1935) is characteristic of the Permian or Upper Carboniferous. It is widely distributed in the Tethyan province, ranging from West Serbia to the Himalyas, China, Japan and Mongolia. The genus is undoubtedly much more abundant in western America than is so far known. To date *Waagenophyllum* has been recorded from rocks of probable Permian age in British Columbia (Crockford and Warren, 1935) and in the Capitan limestone of Texas (Heritsch, 1936, p. 144). To these may be added the Oregon occurrences. In addition specimens probably representing *Wagenophyllum* have been collected by the writer, from the Permian McCloud limestone of northern California. These resemble and may be conspecific with "*Lithostrotion mamillarae* var. *sublaevis* Meek" (Meek, 1864, pp. 5–6; pl. 1, figs. 4–4b) found in the McCloud at "Bass's Ranch," Shasta County, California.

EXPLANATION OF PLATE 54

FIGS. *1–13—Dibunophyllum oregonensis* Merriam, n. sp. Coffee Creek formation, Lower Carboniferous. *1*, Transverse section showing large compact axial structure with large number of lamellae; ×2½; loc. S 93. *2*, Transverse section; axial structure with average number of lamellae; ×2½; loc. S 62. *3*, Transverse section with small number of irregular lamellae in axial structure, median plate thickened; major septa greatly dilated; ×2½; loc. 633. *4*, Transverse section with small rounded axial structure; medial plate not apparent; ×2½; loc. 25A. *5*, Holotype (C. U. 38692); transverse section showing well-defined lamellae and thickened medial plate of axial structure; ×2½; loc. S 2. *6*, Transverse section with unusually dense axial structure; medial plate recognizable; ×2; loc. S 2. *7, 8*, Transverse and longitudinal sections of same individual showing relatively small axial structure with well-defined medial plate; longitudinal section shows crowding and steep inclination of tabellae; ×2; loc. S 62. *9, 10*, Transverse sections of small individuals; ×2; loc. S 62. *11*, Transverse section of large individual; axial structure with unusually straight medial plate; ×2½, loc. S 2. *12*, Transverse section of small individual having a small asymmetrical axial structure; ×2; loc. S 62. *13*, Longitudinal section of average specimen showing large axial structure and broad tabularium; ×2; loc. 633. (p. 373)



Dibunophyllum oregonensis Merriam, n. sp.



Merriam, Permian and Lower Carboniferous Corals

WAAGENOPHYLLUM WASHBURNI
Merriam, n. sp.
Plate 55, figures 2, 5, 7, 9, 11, 13

Holotype, Cornell Univ. no. 38,690.

Corallum fasciculate. Mature corallites cylindrical and straight, with diameter from 12 to 24 mm., average about 15 mm. The septa number about 64, with the major septa occasionally reaching or even penetrating the central column. Minor septa usually less than half the length of the major septa and thinner, rarely extending inward beyond the limit of the dissepimentarium. Major septa slightly dilated within the tabularium. The axial structure is less dense or compact than in species of *Dibunophyllum* and occupies from one-third to one-quarter of the diameter of the corallite, averaging more nearly a quarter. Width of the entire tabularium variable but approximating two-thirds of the diameter of the corallite. The dissepiments in cross section show a herringbone pattern, particularly apparent between the major septa when the minor septa are indistinct, or medially beyond ends of minor septa. In cross section the axial structure is ovoid to subrounded, with a medial plate that is usually somewhat sinuous and little thickened. The septal lamellae often show marked asymmetry between the two sides of the axial complex.

The tabulae are moderately to rather steeply inclined toward the periphery, abuting sharply outward against the wall of the tabularium; medially they frequently extend into the axial complex. Often the tabellae are more steeply inclined than the tabulae, though in a few there is little difference in angle or, in the extreme, the tabulae may be slightly steeper. The dissepiments are small.

Affinities.—*Waagenophyllum washburni* differs from *W. indicum* (Waagen and Wentzel) in its much greater size, in lacking the narrow tabular zone of *indicum*, and in the absence of the large and very steeply inclined dissepiments of the genotype species. The resemblance to *W. columbicum* Smith from the Upper Carboniferous or Permian of British Columbia is, however, apparent. As remarked by Smith (1935, p. 38) the species from Canada is not typical of the genus. One of the figured individuals shows the broad tabular zone of *washburni*. In general however *columbicum* differs in its broader axial structure, narrower tabular region, and somewhat greater density of the axial structure.

Occurrence.—Coyote Butte Permian, locality S 101, south of Grindstone Creek, central Oregon.

WAAGENOPHYLLUM OCHOCOENSIS
Merriam, n. sp.
Plate 55, figures 8, 10; plate 56, figure 3

Holotype, Cornell Univ. no. 38,691.

Corallum fasciculate; cylindrical corallites often in contact and laterally appressed. Diameter of mature corallites ranging from 12 mm. to about 20 mm. The number of septa averages about 60. The major septa are irregular or poorly defined and rarely reach the tabularium. The axial structure is broad (often more than one-third of the diameter of the corallite), rather diffuse or loose, and often highly asymmetrical; though the medial plate is usually recogniza-

EXPLANATION OF PLATE 55

FIGS. *1, 6*—*Waagenophyllum* sp. a. Transverse and longitudinal sections of same individual showing rounded and well-defined axial structure; tabulae horizontal to gently inclined peripherally; ×2; loc. S 87; Coyote Butte Permian. (p. 376)

2, 5, 7, 9, 11, 13—*Waagenophyllum washburni* Merriam, n. sp. *5, 9*, Holotype (C.U. 38690); transverse and longitudinal sections; tabulae well developed; ×2. *2, 11*, Transverse sections of two individuals showing variation in axial structure and width of dissepimental zone; *2*, ×2¼, *11*, ×2, *7, 13*, Transverse sections of two individuals, showing variation in inclination of tabulae and tabellae; ×2. Loc. S 101, Coyote Butte Permian. (p. 375)

3—*Dibunophyllum?* sp. Transverse section; ×2¼. Loc. S 20, Coyote Butte Permian. (p. 373)

4—*Dibunophyllum oregonensis* Merriam, n. sp. Transverse section of aberrant individual; ×2. Loc. L40, Coffee Creek Lower Carboniferous. (p. 373)

8, 10—*Waagenophyllum ochocoensis* Merriam, n. sp. Transverse and longitudinal sections showing loosely constructed axial structure with medial plate; tabellae not well differentiated from tabulae; ×2¼. Loc. 25D, Coyote Butte Permian. (p. 375)

12—*Waagenophyllum* sp. b. Transverse section of two adjoining corallites; ×2¼. Loc. S 20, Coyote Butte Permian. (p. 376)

ble, it is frequently discontinuous and apparently little thickened. Tabulae in outer part of tabular zone approaching horizontal or inclined toward center. Some of the inner peripherally inclined tabulae carry into the axial structure as tabellae, others abut against the axial complex. Lateral increase frequently shown.

Affinities.—*Waagenophyllum ochocoensis* differs from *W. washburni* in having a somewhat looser and on the whole broader axial structure. In *ochocoensis* there appears to be a greater tendency toward medial inclination of the outer tabulae. No individuals showing the narrow tabularium and large steeply inclined dissepiments of *W. indicum* were recognized at the type occurrence of this species. As in *W. washburni*, there is a notable resemblance to some individuals of *W. columbicum*.

Occurrence.—Permian, Coyote Butte formation. Associated with *Parafusulina*. Specimens from loc. S 51 also associated with *Parafusulina* show in longitudinal section the very narrow tabular zone and large steeply inclined dissepiments characteristic of *Waagenophyllum indicum*. Whether this type is a variant of *W. ochocoensis* or possibly *W. washburni* is not known.

WAAGENOPHYLLUM, sp. a
Plate 55, figures 1, 6

Corallum probably fasciculate, cylindrical, with diameter of some mature individuals about 17 mm. Number of septa about 68; some of major septa reaching the axial structure; minor septa weakly defined. Axial structure loose and subrounded in cross section; septal lamellae few, and median plate not well defined. Diameter of axial structure about one-third of diameter of entire corallite. Tabularium broad; tabulae either almost horizontal or gently inclined peripherally; tabulae sometimes straight and continuous from central column to edge of dissepimentarium. Tabellae either steeply or moderately steeply inclined, sometimes tent-shaped. Central column may be sharply set off from tabular zone by very abrupt steepening of tabulae or tabellae.

Affinities.—This form differs from *W. washburni* and *W. ochocoensis* in that some of its tabulae are straight, continuous, and nearly horizontal. The central column is also more sharply defined than in the other two forms, and the number of septal lamellae in the central column appears to be smaller.

Occurrence.—Permian, Coyote Butte formation, locality S 87. Associated with *Parafusulina*.

WAAGENOPHYLLUM sp. b
Plate 55, figure 12

Corallum fasciculate. Mature corallites cylindrical, with diameter of about 13 mm. Septa number about 54; major septa occasionally reaching central column but slightly thickened within tabularium; minor septa well defined, greater than one-half length of major septa, and extending well into tabularium. Central column rather loose, subround in transverse section, with diameter slightly less than one-third that of corallite. Medial plate not well defined.

With its well-defined, little-thickened, and rather long minor septa, this form differs from the other described Oregon species. The characters of the longitudinal section are so far not known.

Occurrence.—Permian, Coyote Butte formation, loc. S 20; associated with *Lithostrotion* (*Lithostrotionella*) *occidentalis*, *Dibunophyllum?*, large cyathophylloids, *Camarophoria karpinskyi*, and *Rhynchopora* sp.

Genus LITHOSTROTION Fleming

Genotype, *Lithostrotion striatum* Fleming, 1828 (see Smith and Lang, 1930, p. 178, and opinion 117 of International Commission on Zoological Nomenclature).

Corals having a compound habit, usually uparching tabulae, an outer dissepimental zone, and a simple axial structure consisting of a thickened plate or rod (columella) have been grouped together in the family Lithostrotiontidae (Grabau, 1927; Sanford, 1939, p. 404). Numerous generic and subgeneric names have been proposed for members of this complex group. Smith and Lang (1930) have reviewed the taxonomy and relationships of certain members of the family and have pointed out the existence of noncolumellate or "diphymorph" corallites among colonies of *Lithostrotion*. Use of the term "genomorph" for "forms which anticipate but do not constitute new genera . . . " is advocated for differentiates of the group. Hill (1933, p. 81) has outlined the various

"trends" in *Lithostrotion*, noting that

> the boundaries of both the genus and its species are extremely difficult to define, since the individuals of all species vary a great deal . . . . The group is more easily dealt with and understood if we postulate that the members of the genus *Lithostrotion* Fleming all possess potentialities to follow definite developmental trends; i.e., characters potentially common to the group as a whole may be expressed or suppressed in different individuals.

The Oregon forms described represent three different groups, which are for the present assigned to described divisions of subgeneric rank. These are as follows: In the Permian, Coyote Butte formation, *Lithostrotion* (*Lithostrotionella*) *occidentalis*, n. sp., and *L.* (*Lithostrotionella*) *berthiaumi*, n. sp. In the Lower Carboniferous, Coffee Creek formation, *L.* (*Siphonodendron*) *oregonensis*, n. sp., and *L.* (*Lithostrotion*) *packardi*, n. sp.

The name *Lithostrotionella* was proposed by Yabe and Hayasaka (1915, p. 93) for Rugosa with a thin columella, broad tabularium, and with septa more or less completely disappearing in a vesiculated peripheral zone. The lonsdaleoid trend with development of the outer vesiculated zone is shown in varying degree by many members of the massive cerioid *Lithostrotion* group. With *L.* (*Lithostrotionella*) *berthiaumi* the lonsdaleoid trend is dominant, while in *L.* (*Lithostrotionella*) *occidentalis* some corallites show nearly all septa continuous outwardly to the epitheca. In *Lithostrotion* (*Lithostrotion*) *packardi* occasional corallites show the vesiculated zone in an incipient stage, but in most instances the septa run peripherally to the outer wall. In a recent paper on North American species of *Lithostrotionella* Hayasaka (1936, p. 54) states that all of the several species considered by him are Mississippian in age. However, in view of the occurrence of the Oregon forms in Permian beds bearing a fusulinid faunule, it is evident that corals of this type have in America a much greater range.

Among Oregon fasciculate types of *Lithostrotion* are those which conform to the characterization of *Siphonodendron* McCoy (Yu, 1933, p. 93; Schindewolf, 1928, p. 148–151; Chi, 1935, p. 21). *Lithostrotion* (*Siphonodendron*) *oregonensis* is a member of this group. One might expect "genomorphs" of the diphyphylloid type among these corals, but so far none have been recognized in the Oregon species; all individuals sectioned show a well-defined axial structure.

LITHOSTROTION (LITHOSTROTION) PACKARDI Merriam, n. sp.
Plate 56, figures 1, 5

Holotype, Cornell Univ. no. 38,693.

Corallum massive, cerioid; epitheca of each corallite rather thin and continuous. Average diameter of mature corallites about 8 mm. Average number of septa 46. Major septa usually stop short of columella but occasionally touch it. Major septa fairly straight and slightly thickened within tabularium, attenuated and often irregular in dissepimental zone, particularly near the periphery, where they are occasionally discontinuous or broken. Minor septa about one-half the length of major septa, often irregular. The minor septa are sometimes broken but in most instances reach the epitheca. Inner margin of dissepimentarium often defined by a false inner wall, along which and medial to which there may be thickening of innermost dissepiments, terminations of minor septa and major septa. Columella a large, narrow, solid, ovoidal rod whose longer axis is about twice the shorter axis. Cross sections of well-preserved specimens show a more or less continuous, faintly marked median lamella and in rare instances weak suggestions of septal lamellae. The diameter of the entire tabularium is somewhat over one-half the diameter of the corallite. Medially the tabulae rise steeply to disappear within the solid columella.

Affinities.—*L.* (*Lithostrotion*) *packardi* closely resembles "*Lithostrotionella*" *hemisphaerica* Hayasaka (1936, p. 61) from the "Lower Carboniferous" of Utah but appears to differ in the character of the tabulae.

Occurrence.—*Lithostrotion packardi* is found in an isolated locality within the Coffee Creek Lower Carboniferous (locality S 75), where it is associated with large fragmentary productids having the appearance of *Gigantella*, with incomplete specimens of a large *Dibunophyllum*, probably *D. oregonensis*, and *Campophyllum? readi*.

LITHOSTROTION (LITHOSTROTIONELLA) OCCIDENTALIS Merriam, n. sp.
Plate 56, figures 2, 4, 7, 8, 11

Holotype, Cornell Univ. no. 38,694.

Corallum massive, cerioid, average diameter of corallites about 6 mm. Average number of septa about 34. Major septa extending to within a short distance of the columella, occasionally touching it. Minor septa ranging in from one-half to two-thirds length of major septa. Columella an oval rod representing the greatly dilated inner termination of one of the primary septa (whether this is the cardinal or the counter septum is not known). Tabularium very narrow or unrecognizable, with inner dissepiments in direct contact with the axial structure. When the narrow tabulae are visible they may be either horizontal or medially inclined. Inner dissepiments steeply inclined to almost vertical; outer dissepiments often large. Where the dissepiments of the outer ring are large the septa do not as a rule reach the epitheca. Epitheca often greatly thickened; dilation affects also the outer ends of the septa.

Remarks.—The septa are frequently broken within the dissepimental zone, terminating on contact with a large dissepiment but recognizable again near the epitheca. There is much variation in the large outer dissepiments, which in some individuals form a continuous outer ring while in others they are few or absent, in which cases nearly all of the septa are continuous to the epitheca. The columellar rod is bisected by the medial plate, which is a continuation of either the cardinal or the counter septum. In some species of *Lithostrotion* the median plate is continuous with both primary septa; in this form one of the primary septa falls short of the axial structure. The one primary septum which leads into the columella is often appreciably thickened.

Occurrence.—Permian, Coyote Butte formation. Locality S 20, with *Camarophoria karpinskyi* Tschernyschew and *Rhynchopora* sp. Loc. S 102, variety with unusually thick wall; occurs with *Parafusulina*.

LITHOSTROTION (LITHOSTROTIONELLA) BERTHIAUMI Merriam, n. sp.
Plate 56, figures 9, 10

Holotype, Cornell Univ. no. 38,695.

Corallum massive, cerioid, polygonal outline of corallites very irregular; average greatest diameter about 7 mm. Number of septa 20 to 22; minor septa often poorly developed or unrecognizable. Major septa usually short and peripherally dilated, with attenuated terminations occasionally reaching axial structure. Transverse section shows well-defined false inner wall between tabularium and dissepimentarium. Septa do not extend peripherally beyond this ring. Columella usually developed as a lens-shaped (in transverse section) solid rod of unusual strength, rarely showing well-defined connection with a primary septum. Medial plate rarely well defined. Faint radial markings suggesting lamellae are sometimes recognizable. Dissepimentarium in transverse section appears broad, as in some species of *Lonsdaleia*, and with unusually large individual dissepiments. Epitheca somewhat thickened. In longitudinal section the large dissepiments are often steeply inclined. The tabulae are relatively broad, usually continue without interruption from dissepimentarium into

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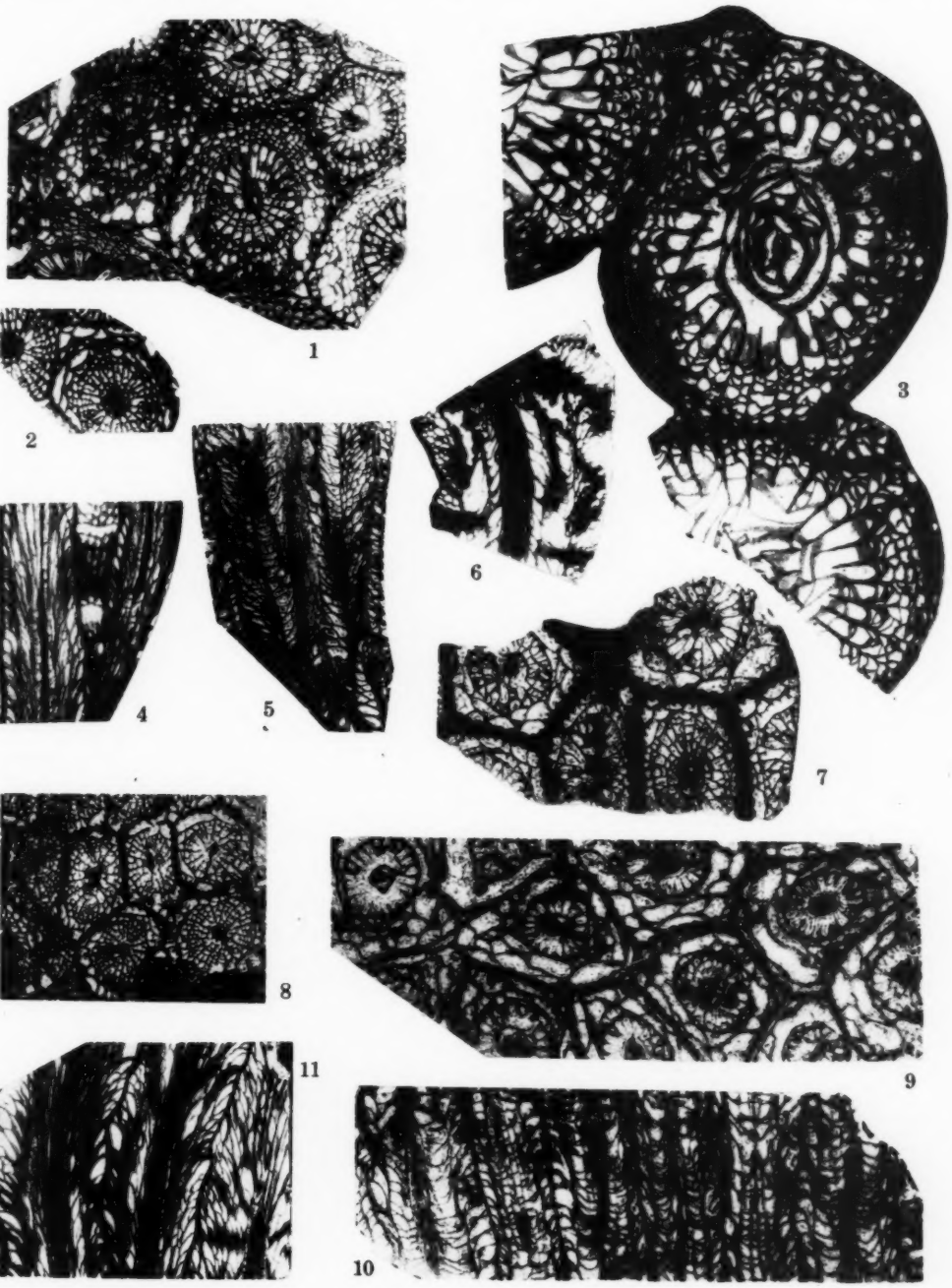
EXPLANATION OF PLATE 56

FIGS. *1, 5, 6—Lithostrotion* (*Lithostrotion*) *packardi* Merriam, n. sp. *1, 5*, Holotype (C.U. 38693); transverse and longitudinal sections showing thickened columella and slightly vesiculated outer zone of some corallites; *1*, ×2½; *5*, ×2½; loc. S 75. *6*, (Cf. *packardi*), longitudinal section; ×2½; loc. S 2. Coffee Creek Lower Carboniferous. (p. 377)

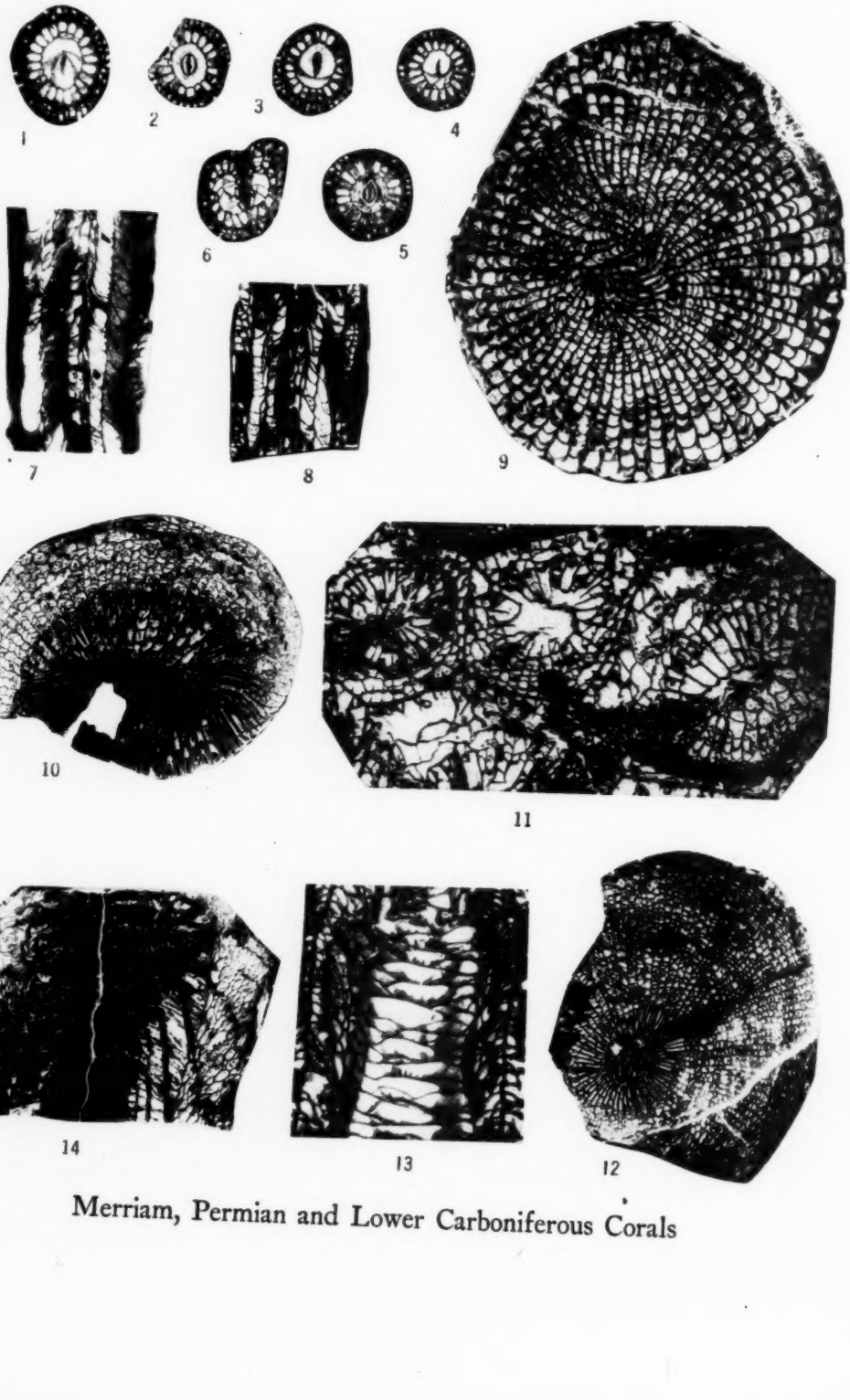
2, 4, 7, 8, 11—Lithostrotion (*Lithostrotionella*) *occidentalis* Merriam, n. sp. *2, 11*, Transverse and longitudinal sections of same individual showing heavy columella joined to thickened primary septum, vesiculated outer zone and almost complete absence of visible tabulae; ×2½; loc. S 20. *4, 8*, Holotype (C.U. 38694); longitudinal and transverse sections, showing columella, vesiculated peripheral zone, very narrow zone of tabulae and thickened epitheca; ×2½; loc. S 20. *7*, Transverse section of form with greatly thickened epitheca; ×2½; loc. S 102. Coyote Butte Permian. (p. 377)

3—Waagenophyllum ochocoensis Merriam, n. sp. Transverse section of holotype (C.U. 38691); ×2½. Loc. 25D, Coyote Butte Permian. (p. 375)

9, 10—Lithostrotion (*Lithostrotionella*) *berthiaumi* Merriam, n. sp. Holotype (C.U. 38695). Transverse and longitudinal sections showing thickened columella, strongly vesiculated peripheral zone and axial inclination of tabulae; ×2½. Loc. S 80, Coyote Butte Permian. (p. 378)



Merriam, Permian and Lower Carboniferous Corals



Merriam, Permian and Lower Carboniferous Corals

central axis, and are generally concave upwards and as a whole inclined medially though rising upward before meeting the columella. The downward curvature and continuity of the tabulae appears to be highly characteristic.

Remarks.—Downward curvature of the long tabulae, strength of columella, and large size of dissepiments is a combination of characters not found in other known American species of *Lithostrotionella*. *Lithostrotionella simplex* Hayasaka from Paradise Canyon, Wasatch Range, Utah, shows long tabulae which often have a slight downward curvature, similar dissepiments, and a strong false inner wall. In the Utah form, however, the columella appears to be rather weakly developed and the septa somewhat shorter.

Occurrence.—Permian, Coyote Butte formation, locality S 80; *Parafusulina* found at loc. S 81 near the horizon of S 80.

LITHOSTROTION (SIPHONODENDRON) OREGONENSIS Merriam, n. sp.
Plate 57, figures 1–8.

Holotype, Cornell Univ. no. 38,696.

Corallum fasciculate, corallites cylindrical, rarely in contact, roughly parallel, with average diameter of about 5 mm. Outer wall sometimes thin. Number of septa from 34 to 40, minor septa approximately one-half the length of major septa. Major septa terminate some distance short of columella in an inner ring, which in cross section resembles an aulos though not homologous with that of *Aulina*. Between the inner ring and the outer wall but nearer the last is a stereozone at the inner border of the dissepimentarium, within which the minor septa terminate. The major septa are nearly always thickened between the stereozone and the inner ring; occasionally dilation affects septa between stereozone and outer wall. The dissepimentarium is rather narrow, the dissepiments small, frequently approaching horizontality near the periphery, though the inner ones are often nearly vertical. Tabularium broad. Tabulae occasionally continuous from dissepimentarium to central axis, more commonly discontinuous. Near stereozone outer tabulae often horizontal; inner tabulae or inner ends of continuous tabulae may rise almost vertically before crossing the axial zone. Axial structure a narrow columella bisected by a median plate, which is not connected with primary septa. No "diphymorphs" lacking the columella have been observed.

Affinities.—*Lithostrotion* (*Siphonodendron*) *oregonensis* resembles members of this genus from the Lower Carboniferous of China (Yu, 1933, p. 93), particularly *L.* (*Siphonodendron*) *irregulare* (Phillips) Yu but differs in greater diameter of corallites, heavier development of stereozone, greater thickening of major septa, greater width of dissepimental zone, and general lack of connection between columella and primary septa as seen in cross section. *Lithostrotion whitneyi* Meek from the Carboniferous of the Wasatch Range differs in possessing major septa that extend inward almost to the columella.

Occurrence.—*Lithostrotion* (*Siphonodendron*) *oregonensis* is one of the most characteristic forms of the Coffee Creek Lower Carboniferous; it has been found in nearly all outcrops of this formation, occurring in limestones and argillaceous limestones. It is associated with *Dibunophyllum oregonensis*, *Gigantella*, and *Striatifera*.

POSITION UNCERTAIN

Four of the Oregon rugose species have not been placed definitely with respect to generic position. Of these one from the Coy-

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EXPLANATION OF PLATE 57

FIGS. *1–8*—*Lithostrotion* (*Siphonodendron*) *oregonensis* Merriam, n. sp. *1–6*, Holotype (C.U. 38696); Transverse sections of individual corallites; ×2½; loc. S 93. *7*, *8*, Longitudinal sections of two corallites; ×2½; Loc. S 2. Coffee Creek Lower Carboniferous. (p. 379)

9—*Cyathophylloid* sp. b. Transverse section; ×2½. Exact locality uncertain, may be from Coffee Creek Lower Carboniferous. (p. 380)

10, *14*—*Campophyllum? readi* Merriam, n. sp. *10*, Holotype (C.U. 38697); transverse section; ×1; loc. S 2. *14*, Longitudinal section ; ×1; loc. 633. Coffee Creek Lower Carboniferous. (p. 380)

11, *13*—*Lithostrotion?*, genomorph *Diphystrotion* sp. Transverse and longitudinal sections of same corallum, ×2½. Loc. S 80, Coyote Butte Permian. (p. 380)

12—*Cyathophylloid* sp. a. Transverse section; ×1. Loc. S 20, Coyote Butte Permian. (p. 380)

ote Butte Permian has somewhat the habit of *Prismatophyllum* but may represent a genomorph of the *Lithostrotion* group to which the "genomorphic" name "Diphystrotion" has been applied by Smith and Lang (1930, pp. 179, 184, pl. 7, figs. 14, 15). The remaining three probably represent the Cyathophyllidae.

LITHOSTROTION? genomorph
DIPHYSTROTION sp.
Plate 57, figures 11, 13

Corallum massive, cerioid. Corallites large, with average diameter about 13 mm. Number of septa about 44. Major septa extending at least two-thirds of the distance from epitheca to center of corallite; minor septa sometimes greater than one-half length of major septa. Both major and minor septa often broken or discontinuous peripherally. Dissepimental zone with large and small discontinuous and irregular vesicular areas. No axial structure. Dissepimental zone fairly broad, numerous very large dissepiments intermingled with the small ones. Tabularium broad. Tabulae range from nearly horizontal and continuous to discontinuous and uparched, both large and small.

The form described herein bears a notable resemblance to *Lithostrotion* sp., genomorph *Diphystrotion kendalense* Smith and Lang (1930, p. 186), from the Lower Carboniferous of Westmoreland.

Occurrence.—Permian Coyote Butte formation, locality S 80, associated with *Lithostrotion* (*Lithostrotionella*) *berthiaumi*.

CAMPOPHYLLUM? READI
Merriam, n. sp.
Plate 57, figures 10, 14

Holotype, Cornell Univ. no. 38,697.

Simple cyathophylloids of large size; average diameter of mature corallum about 40 mm. Average number of septa about 92. Major septa extending somewhat over two-thirds of the distance from the outer wall to the center of the corallum, thin and sinuous within the dissepimental zone, straighter and considerably dilated within the tabularium. Minor septa thin, sinuous, often discontinuous, rarely reaching inner border of dissepimental zone. Dissepimental zone broad, usually about one-half the distance from outer wall to center. Width of tabularium may be greater than one-half diameter of corallite. Tabulae horizontal or with moderate downward inclination toward the periphery. No fossula or axial structure has been observed.

Campophyllum? readi resembles *Cyathophyllum* (*Campophyllum?*) *nevadense* Meek from the Carboniferous of the Wasatch Range, Utah. The Oregon form differs in possessing a broader dissepimental zone and (according to the figure of Meek) dilation of the inner portions of major septa.

Occurrence.—*Campophyllum? readi* is one of the commonest fossils in the Coffee Creek Lower Carboniferous. It is found in association with *Dibunophyllum oregonensis* and *Gigantella*.

CYATHOPHYLLOID sp. a
Plate 57, figure 12

A large cyathophylloid with diameter of 50 mm. Number of septa great (about 120). Major septa do not reach the center; short inner ends dilated within the tabularium. As seen in transverse section the dissepiments are close-set, particularly toward the periphery; the dissepimental zone extends two-thirds of the distance from the outer wall to the center.

Occurrence.—Permian, Coyote Butte formation, locality S 20.

CYATHOPHYLLOID sp. b
Plate 57, figure 9

Corallum simple, with diameter about 22 mm. Number of septa about 70. Most of the major septa long enough to reach center, where there is an axial twisted zone (axial vortex) similar to that of *Ptychophyllum stokesi* Edwards and Haime. Minor septa long, sometimes approaching three-fourths length of major septa. Dissepimental zone very extensive; some dissepiments appear to lie even within the axial vortex. Spacing of dissepiments in peripheral zone greater than within.

Occurrence.—Possibly Coffee Creek Lower Carboniferous. Found in the Grindstone Creek Paleozoic area, but exact locality unknown.

LOCALITIES

Bearings from Wade Butte (Dayville quadrangle) are from highest point on east side.

Coyote Butte Permian

S 20. 3¾ miles S. 61° E. of Wade Butte. South side of Grindstone Creek.
S 51. West side of ridge at south end ½ mile N. 10° E. of Tucker's Butte, 4¾ miles south of Wade Butte.
S 80. Top of ridge 2½ miles S. 77° E. of Wade Butte.
S 87. Near top of ridge 2 miles S. 37° E. of Wade Butte.
S 101. South side of Grindstone Creek, 3¼ miles S. 50° E. of Wade Butte.
S 102. South side of Grindstone Creek ¼ mile southwest of S 20, 3⅜ miles S. 56° E. of Wade Butte.
25 D Near top of ridge ⅛ mile east of S 87, 2 miles S. 41° E. of Wade Butte.

Coffee Creek Lower Carboniferous

S 2. On limestone ridge ½ mile east of Mills' sheep camp 1⅜ miles S. 47° E. of Wade Butte.
S 62. One-eighth mile north of Twelvemile Creek 4⅛ miles S. 29° E. of Wade Butte.
S 75. East side of ridge ⅜ mile south of Grindstone Creek, 3⅞ miles S. 60° E. of Wade Butte.
S 93. One-half mile southwest of S 2, 1½ miles S. 37° E. of Wade Butte.
L 40. Three-eighths mile east of S 2, 1⅜ miles S. 53° E. of Wade Butte.
25 A. Three-fourths mile north of Twelvemile Creek, 3½ miles S. 20° E. of Wade Butte.
633. Probably the same as S 2.

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SAROCRINUS, A NEW CRINOID GENUS FROM THE LOWER MISSISSIPPIAN

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A NEW CRINOID genus, *Sarocrinus*, is proposed for the reception of three new species and four species previously described. As known the genus is restricted to the lower Mississippian. The affinities of *Sarocrinus* seem to be with *Zeacrinus*, and it may be ancestral to that genus. A new family, Zeacrinidae, is proposed.

Family ZEACRINIDAE Kirk, n. fam.

Crown short, compact. Dorsal cup basin-shaped. Ventral sac stout, composed of numerous small plates. *IBr* one or two except in *ant R*, where typically there are more than two. Arms stout, endotomous, except in the earliest known genus, where the more primitive dichotomy obtains. Typically three anal plates in the *post IR*, but some of these may pass out of the cup in the later genera.

The family includes the following genera: *Eratocrinus*, *Sarocrinus*, *Zeacrinus*, *Alcimocrinus*, *Paraburšacrinus*, and *Neozeacrinus*.

The geological range of the Zeacrinidae is from the base of the Mississippian to the Permian as known.

Remarks.—A plausible evolutionary line would be *Sarocrinus-Zeacrinus-Paraburšacrinus*. *Eratocrinus* and *Alcimocrinus* are included in the family in part because of probable affinity and in part because they seem to have little near kinship to other known crinoid groups.

The family Zeacrinidae replaces in part the Scaphiocrinidae of Bather. The family as made by Bather was based on an erroneous conception of *Scaphiocrinus*, which now falls into synonymy with *Graphiocrinus*.

Genus SAROCRINUS Kirk, n. gen.

Genotype, *Sarocrinus nitidus* Kirk, n. sp.

Crown: Small, compact, subcylindrical.

Dorsal cup: Low, saucer-shaped; truncate base, with deep basal pit.

IBB: Small, lying in basal pit, and concealed by column.

BB: Small, the proximal portions forming the wall of the basal pit, the distal parts extending upward and outward in the sides of the cup.

RR: Large, relatively wide. Articulating facet linear to slightly crescentic. Suture slightly gaping.

IBr: Stout. Two in number except in *ant R*, where they range in number from three to eight as seen.

Arms: Short, stout. But one dichotom in *ant R*. In other rays a second isotomous division takes place. One species, *Zeacrinus keokuk* Worthen, is included, in which there is a second isotomous division in the *ant R* and endotomous division obtains in the other rays. *Br* quadrangular to slightly cuneate.

Post *IR:* Three anal plates in cup. *RA* seated well down between *post* and *r post BB*, large, about as wide as high. *X* rises well above the level of the *RR*, as also does *RT*.

Ventral sac: Short, stout, composed of numerous small plates.

Column: Typically circular in section, composed of well-defined series of nodals and internodals. The column of the Burlington species is obscurely pentagonal in section.

Characteristic species of the genus.—The following species are referred to *Sarocrinus:*

Sarocrinus carinatus Kirk, n. sp. Upper part upper Burlington limestone "Burlington-Keokuk transition beds," Burlington, Iowa.

Sarocrinus granilineus (Miller and Gurley) [*Poteriocrinus*]. Miller and Gurley, 1890, p. 22, pl. 4, fig. 7. "Keokuk group, Crawfordsville, Indiana."

Sarocrinus? keokuk (Worthen) [*Zeacrinus*]. Worthen, 1882, p. 28; "Upper part of geodiferous shales, one mile below Keokuk, Iowa." 1883, p. 303, pl. 28, fig. 3.

Sarocrinus nitidus Kirk, n. sp. Upper Borden, Indian Creek, Montgomery County, Indiana.

Sarocrinus plenus Kirk, n. sp. Borden, near Canton, Washington County, Indiana.

Sarocrinus pocillum (Miller) [*Zeacrinus*]. Miller, 1891, p. 28, pl. 4, figs. 1, 2. "Keokuk group, Boonville, Cooper County, Missouri." (Probably Warsaw.)

Sarocrinus tentaculatus (Worthen) [*Poteriorinus*]. "Upper shales of geode bed, 1 mile below Keokuk, Iowa."

Geologic and geographic distribution.—Characteristic species of *Sarocrinus* range from the upper Burlington to the Warsaw, being found in the Burlington and Keokuk of Iowa, the Borden of Indiana, and the Warsaw of Missouri. There is also in the Springer Collection a poorly preserved crinoid referable to *Sarocrinus* from the "Waverly" of Richfield, Ohio.

Relationships.—Superficially *Sarocrinus* resembles *Woodcrinus*. The turbinate cup and single *IBr* of *Woodcrinus* as against the shallow basin-shaped cup, two *IBr*, and numerous *IBr* in the *ant R* of *Sarocrinus* are the most striking differences. *Sarocrinus* may be distinguished from *Zeacrinus* by the arm structure and the anal plates. The two *IBr* and isotomous arms of *Sarocrinus* as against the one *IBr* and endotomous arms of *Zeacrinus* are the most obvious differences. In *Sarocrinus* the anal plates are large, subequal in size, and of approximately equal height and breadth. The compressed anal plates of *Zeacrinus*, especially the elongate *RA* penetrating deeply within the basal circlet, are quite unlike *Sarocrinus*.

Zeacrinus might readily be derived from *Sarocrinus*. Either by the fusion of the two *IBr* in *Sarocrinus* or by atrophy of one brachial this structure would have passed into that of *Zeacrinus*. The passage from isotomy to endotomy is a normal evolutionary process. The *post IR* of *Zeacrinus* could readily be derived from *Sarocrinus*. Fairly characteristic *Zeacrinus* are found in the St. Louis. There seems to be little doubt of the provenance of the specimens.

In the Keokuk is found the interesting species *Zeacrinus keokuk* Worthen. The holotype has four *IBr* in the *ant R* and one in the other rays. In the anterior ray there is a single isotomous division above the *IAx*. The other rays are endotomous, there being three divisions above the *IAx*. The posterior interradius is not shown. Another specimen, also originally in the Cox Collection, agrees in general habit and in arm branching with the type of *Z. keokuk*. In this specimen there are, however, seven *IBr* in the *ant R* and two in the others. In both specimens the dorsal cups are unsatisfactory in that they are crushed and do not show the *post IR*. If the two specimens are conspecific, which seems possible, one is a saltatory variant of the other. With our present knowledge of these forms it seems probable the two-*IBr* condition is the normal and, unfortunately, the type is the abnormal form. At any rate I am tentatively referring the species to *Sarocrinus*, giving one species with endotomous arm structure in the genus. The species is what one would expect as representing a transitional group between *Sarocrinus* and *Zeacrinus*. If the structure of the posterior interradius were sufficiently unlike, it is possible that a group of Keokuk, Warsaw, St. Louis, and possibly later species might be separated from *Sarocrinus* and *Zeacrinus*. The specimen figured by Worthen (1883, pl. 27, fig. 3a) as *Poteriocrinus orestes* is probably *S. keokuk*. Figure 3, which is here selected as holotype of the species, is referable to *Abrotocrinus* and should be cited as *Abrotocrinus orestes* (Worthen). Figure 3a is badly crushed but in all the characters shown agrees with *S. keokuk*. It is interesting to note that here again there is a single *IBr*. The persistence of the *IIBr* stock is suggested by the Pennsylvanian genus *Alcimocrinus*. This genus, though not in the direct *Zeacrinus* line, seems to be nearly related.

Remarks.—I have figured (pl. 58, fig. 10) a specimen from the Lyon Collection, now in the Springer Collection in the United States National Museum S 4408. It is labeled as from "Upper layers, Crawfordsville, Indiana." It is the largest specimen of *Sarocrinus* known to me. It probably represents a new species, but owing to the crushed condition of the dorsal cup it has not seemed desirable to give it a name.

SAROCRINUS CARINATUS Kirk, n. sp.
Plate 58, figures 1–7

Of this species but four specimens are known, all of which are figured. One specimen is in the Wachsmuth Collection in the Museum of Comparative Zoology and bears a label in Wachsmuth's handwriting "*Scaphiocrinus* n. sp." The other three specimens were in unworked material derived from the

"Burlington-Keokuk transition beds," quarried at Ninth and Angular Streets, Burlington, Iowa.

The crown is compact and relatively slender. The crown of the holotype has a height of 30 mm. The dorsal cup of this specimen has a height of 2 mm. and a maximum diameter of 7 mm. The surface of the arms and cup is finely granulose, scarcely to be detected even with a lens. The dorsal cup has a broadly truncate base and a large shallow basal pit. The plates of the cup are tumid.

The *IBB* are small and completely concealed by the column. The *BB* are large, not more than one-third their area lying within the basal depression, the remainder forming the cup wall. The *RR* are broad and low. *RA* is large, penetrating deeply between *post* and *r post BB* and extending upward to nearly the top of the cup. Anal *X* supports an unusually large *RT* on its upper right shoulder and a smaller tube plate above.

The arms are relatively long and slender for the genus. Beginning on the *IBr* and extending at least to the *IIAx* there is a median crest or ridge. Distad the backs of the brachials are smoothly rounded. The union between the brachials was weak, and dissociation or lateral shift between successive brachials is common. In the only specimen where the anterior radius is well preserved there are eight primibrachs.

The column is pentagonal, with rounded angles in the proximal portion.

The immature specimen figured, in addition to customary juvenile characteristics, shows a smoothly rounded cyathiform cup and a small basal pit. Only the proximal tips of the basals are involved in the pit.

Horizon and locality.—The exact horizon and locality of the Museum of Comparative Zoology specimen are unknown other than "Upper Burlington, Burlington, Iowa." The three specimens in the Springer Collection are from the high upper Burlington (Burlington-Keokuk transition beds) at the Ninth and Angular Streets quarry, Burlington, Iowa.

Types.—The holotype, S 4405a, (pl. 58, figs. 1–3) and paratypes S 4405b and c (pl. 58, figs. 6, 7) are in the Springer Collection, United States National Museum. Another paratype (pl. 58, figs. 4, 5) is no. 1430 (Wachsmuth's original catalogue No. 356) in the Museum of Comparative Zoology, Cambridge, Mass.

Relationships.—*Sarocrinus carinatus* shows little resemblance to any known species of *Sarocrinus*. The bowl-shaped dorsal cup with its tumid plates is quite unlike any other species. The relatively long slender arms are comparable only to those of *S. plenus*, from which it may readily be distinguished by the sharply carinate *IBr* and proximal *IIBr*.

SAROCRINUS TENTACULATUS (Worthen), n. comb.
Plate 58, figure 21

Poteriocrinus iowensis WORTHEN, *1882*, p. 6; *1883*, p. 272.
Poteriocrinus tenuidactylus WORTHEN, *1882*, p. 10. [Not Worthen *1882*, p. 6, nor *P.* (*Scaphiocrinus*) *tenuidactylus* Meek and Worthen, *1865*.]
Poteriocrinus tentaculatus WORTHEN, *1882*, p. 227, pl. 28, fig. 11. [New name for *P. tenuidactylus* Worthen, *1882*, p. 10.]
Woodocrinus tentaculatus, WACHSMUTH and SPRINGER, *1886*, p. 242 (166).

I refigure the holotype of this species. On the same piece of rock, *verso*, is the type of *Poteriocrinus iowensis* Worthen. This specimen was never figured. It obviously is also

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EXPLANATION OF PLATE 58

FIGS. *1–7*—*Sarocrinus carinatus* Kirk, n. sp. *1*, Anterior; *2*, basal; and *3*, posterior views of holotype (*1*, *3*, ×1; *2*, ×1½). *4*, Basal, and *5*, posterior, views of a paratype, M.C.Z., ×1½. *6*, Posterior view of young specimen, paratype, ×1½. *7*, Posterior view of a paratype, ×1. (p. 383)

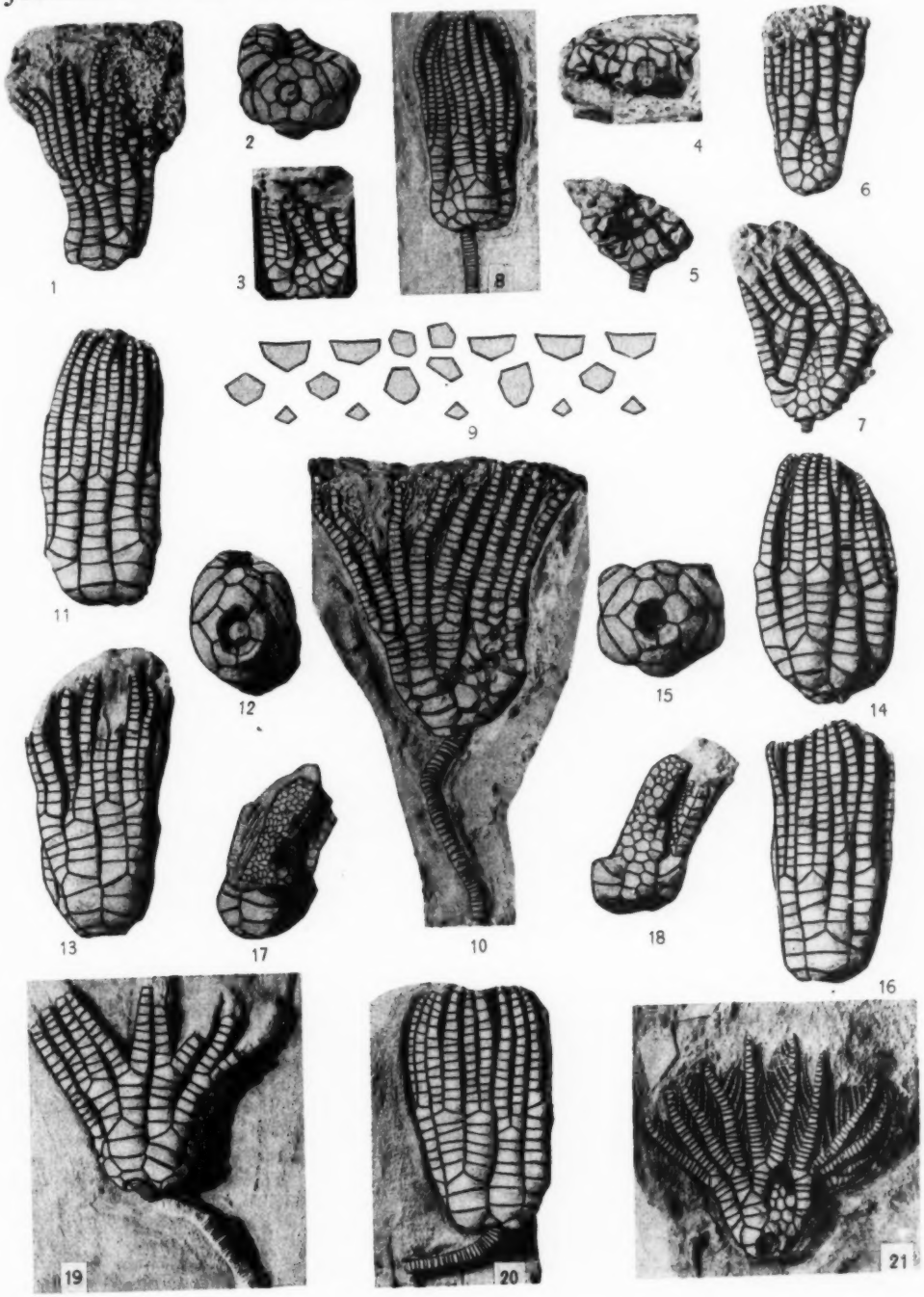
8—*Sarocrinus plenus* Kirk, n. sp. Right posterior view of holotype, ×1. (p. 386)

9—Plate diagram of *Sarocrinus*. (p. 382)

10—*Sarocrinus* sp., ×1. (p. 383)

11–20—*Sarocrinus nitidus* Kirk, n. sp. *11*, Anterior view of holotype, ×1½. *12*, Basal view, ×2, and *13*, right posterior view, ×1½, of a paratype. *14*, Right anterior view, ×1½, of a paratype. *15*, Basal view, ×2; *17*, left posterior view, ×1½; and *18*, posterior view, ×1½, showing ventral sac of a paratype. *16*, Left anterior view, ×1½, of a paratype. *19*, Right posterior view of a paratype, ×1½. *20*, Anterior view of a paratype, ×1½. (p. 385)

21—*Sarocrinus tentaculatus* (Worthen), n. comb. Posterior view of holotype, ×1. (p. 384)



Kirk, Mississippian Crinoids

referable to *Sarocrinus*. The specimen is crushed and was badly mutilated in preparation. It is a smaller individual than the type of *Sarocrinus tentaculatus*, but, from such characters as can be seen, there seems no good reason for separating it from *S. tentaculatus*.

The dorsal cup of the holotype of *Sarocrinus tentaculatus* has been distorted by crushing. The basal pit is sharply defined and deep. Only a small part of the basals flex inward to form the wall of the pit. The surface of the plates is granulose, the granules tending to coalesce and form vermicular ridges. The posterior interradius is wider than in any known species of the genus. Both *IBr* and *IIBr* series of the *r* and *l post RR* are widely separated in the *post IB*, and even in an uncrushed specimen it is doubtful if the *IIIBr* series met over the *post IR*.

The arms are short and stout, tapering rapidly distad. The *IIBr* series are very short. In the *r* and *l post RR* three half-rays are shown. In each of these there are but four *IIBr*. In the *l ant R* one-half the ray is shown. There are six *IIBr*, but even here the *IIBr* series is relatively short compared with the total length of the arms. Worthen describes the *ant R* of *Poteriocrinus iowensis* as probably having five *IBr* and bifurcating again on the third secundibrach. In the specimen itself the anterior ray is badly preserved and disarranged. It does appear as described by Worthen. As a matter of fact, there seems to have been a further division on the third *IIIBr* in one series. Such a condition suggests regeneration after injury, when irregular and sometimes multiple bifurcations are induced. One may not, I think, take this structure as typical or even normal until confirmed by other specimens.

Horizon and locality.—"Upper shales of the geode bed 1 mile below Keokuk, Iowa." By some the geode bed is placed in the Warsaw, but it seems better held in the Keokuk, at least until such time as the Warsaw is better known. At any rate, the crinoid fauna of the geode bed at Keokuk is quite unlike the crinoid fauna commonly ascribed to the Warsaw.

Type.—The holotype of *Sarocrinus tentaculatus*, formerly in the Cox Collection, is now in the Springer Collection, United States National Museum, S 2709. The type of *Poteriocrinus iowensis* is catalogued as S 2608.

SAROCRINUS NITIDUS Kirk, n. sp.
Plate 58, figures 11–20

This species has been chosen as genotype because of the wealth of material available. More than 70 specimens of the species are found in the Springer Collection in the United States National Museum alone. Most of these are complete crowns in an excellent state of preservation.

The average height of the crowns is about 25 mm. The crown is compact and subcylindrical when uncrushed. The dorsal cup is patelliform, with a deeply excavate base. The surface of the cup and arms is covered with small granules that tend to coalesce.

The *IBB* are very small and lie at the bottom of the deep basal pit, being completely hidden by the column. The basals form the wall of the basal pit, extending outward and upward to nearly one-half the height of the dorsal cup. The *post B* is also large, normally making contact with *RA*. In some cases *RA* barely touches *r post R*, and in at least one specimen the two plates do not meet. The *RR* are large, with the linear to slightly curved articulating facet extending the full width of the plate. The suture is slightly gaping. *RA* is normally pentagonal in outline, elongate, and with the long axis at a high angle. In cases where the *RA* does not contact the *r post B* the *RA* is an elongate quadrangular kite-shaped plate. Anal *X* is large, resting below on *post B* and *RA*. On its upper right shoulder it supports *RT* and above a large tube plate. Anal *X* extends upward nearly or quite to the top of IBr_1. The ventral sac is composed of numerous small plates. It is short, stout, and reflexed.

The arms are short, stout, and usually in lateral contact throughout their length, except in the posterior interradius. Even here, however, the rami on either side converge rapidly and meet at the level of the third or fourth *IIBr*. The brachials are broad, with slightly arching backs. The faces of the brachials slope slightly in the proximal portions of the arms and are subparallel distad. There are two *IBr* in all rays except the anterior. In the anterior ray the most frequent number of *IBr* is six, but as many as seven or eight *Br* are found. In the anterior radius

there is but one isotomous division. In all other rays there is an isotomous division in each half ray above the main dichotom. The pinnules are long and stout.

The column is circular in section, slender, and composed of well-defined series of nodals and internodals.

Types.—The holotype, S 4406a (pl. 58, figs. 15, 16), and paratypes, S 4406b–h (pl. 58, figs. 11–14, 17–20), are in the Springer Collection, United States National Museum.

Horizon and locality.—All known specimens referred to the species are from the upper Borden of Indian Creek, Montgomery County, Indiana.

Relationships.—The species most nearly resembling *Sarocrinus nitidus* is *S. granilineus* (Miller and Gurley) from the Borden of Crawfordsville, Ind. In *S. granilineus* the backs of the arms are subangular and for the greater part of their length are sharply keeled. The surface of the plates of the entire crown is "strongly granulated." In *S. nitidus* the backs of the arms are smoothly rounded, and the surface of the plates is finely granulose.

SAROCRINUS PLENUS Kirk, n. sp.
Plate 58, figure 8

I have seen but a single specimen of this species. Although there is a complete crown with a portion of the column attached, the specimen is somewhat unsatisfactory in that it is partially silicified and at some time or other has been treated with acid. It seems to be clearly unlike other species of the genus known, and, in order to clear up all the known material, it has seemed best to describe it.

The crown is compact, subcylindrical, and of medium size, having a height of 31 mm. The dorsal cup is broad and low, with a height of but 2 mm. and a diameter of 9 mm. Instead of a sharply defined basal pit the basal area is shallowly excavate. The plates of the dorsal cup are tumid. Although the surface of the plates is poorly preserved, it appears that the plates of the dorsal cup and brachials were papillose.

The *IBB* are small and concealed by the column. The *BB* are large and have an almost horizontal attitude, only a small portion being visible in lateral view. The basal depression is wide and shallow, in contrast to the relatively narrow, sharply defined basal pit of most of the species of the genus. *RA* extends upward to the top of the cup. Anal *X* is proportionally very large in the type specimen and *RT* comparatively small. There is considerable variation in the size and proportions of the plates of the *post IR*, however, and these characters may not be significant.

The arms are relatively long and slender, more so than in any known species of this approximate age. There is a low but well-defined keel on the first primibrach that does not seem to continue distad.

Horizon and locality.—Borden, near Canton, Washington County, Ind. The stratigraphic position of this crinoid "nest" is unknown, but it is assumed that it lies within the Borden.

Type.—The holotype is in the Springer Collection, United States National Museum S 4407. It was probably collected by Charles Wachsmuth, who was taken to the locality in the early days by Borden himself.

Relationships.—*Sarocrinus plenus* may readily be distinguished from the other two Borden species, *S. nitidus* and *S. granilineus* (Miller and Gurley), by its relatively long, slender arms and by its shallowly excavate base without a sharply defined basal pit.

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CORRECTION OF HOMONYMS IN THE LAMELLIBRANCH GENUS CONOCARDIUM

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ABSTRACT—Eleven homonyms in the genus *Conocardium* are replaced. Two poorly known species, *C. ventricosum* Hall and *C. antiquum* (Owen), equal to *C. antiquatum* Branson, n. name, are described and figured. *C. altum* Keyes is referred to the synonymy of *C. ventricosum*.

SPECIMENS of the peculiar lamellibranch *Conocardium* are locally abundant in Paleozoic rocks younger than Cambrian (reports of Triassic species seem erroneous) and are rare fossils in many Paleozoic formations. The literature of the genus is more scattered than is usual for such a group, and many of the 251 trivial names that have been proposed are homonyms.

The writer has received generous aid from many geologists during the preparation of this and of contemplated papers on the genus *Conocardium*. For the loan of specimens studied in this paper he acknowledges the kindnesses of Dr. Lowell Laudon of the University of Tulsa, Dr. E. Leith of the University of Manitoba, Drs. A. K. Miller and W. M. Furnish of the University of Iowa, Dr. G. A. Cooper of the United States National Museum, Mr. M. E. Chappars of the University of Chicago, and Dr. R. E. Peck of the University of Missouri.

The following nomenclatorial changes are proposed:

CONOCARDIUM TRIPARTITUM Pohl, n. name

Conocardium truncatum POHL [not De Koninck], *1929*, Milwaukee, Public Mus., Bull., vol. 11, no. 1, p. 53, pl. 7, figs. 5–6.

The trivial name is preoccupied by *C. truncatum* de Koninck (1885). Mr. Pohl suggested the present new name when advised of the previous use of his trivial name (personal communication, May 22, 1939). The species occurs in the Lake Church formation (Devonian) at Lake Church, Ozaukee County, Wisconsin.

CONOCARDIUM VENTRICULOSUM Tolmachoff, n. name

Conocardium ventricosum TOLMACHOFF [not Hall], *1926*, Norske vidensk.-akad. Oslo, Second Norwegian Arctic Exped. Rept., no. 38, suppl., p. 74, pl. 6, figs. 12, 13.

Dr. Tolmachoff[1] suggests the new name to replace *C. ventricosum* Tolmachoff, homonym of *C. ventricosum* Hall (1860). The species occurs in the Devonian of Ellesmere Land. Hall's species is redescribed and is figured for the first time in this paper.

CONCARDIUM PLINTHINATUS Branson, n. name
Plate 59, figure 18

Conocardium ornatum CLELAND [not Winchell and Marcy], *1911*, Wisconsin Geol. and Nat. History Survey, Sci. ser., Bull. 21, p. 108, pl. 21, figs. 9, 10.

Conocardium ornatum, POHL, *1929*, Milwaukee, Public Museum, Bull., vol. 11, p. 52, pl. 7, figs. 2–4.

Cleland's trivial name is preoccupied by *C. ornatum* Winchell and Marcy (1865). No well-preserved specimen of the species is known. It is certainly of the group of *C. subtrigonale* d'Orbigny, a group which is abundant in Lower Devonian and Hamilton rocks. The species occurs in Zone C of the Milwaukee formation in the Berthelet section of Milwaukee, Wisconsin.

CONOCARDIUM? HAMLETAE Branson, n. name

Conocardium ornatum HAMLET [not Winchell and Marcy], *1928*, Dutch East Indies Dienst van den Mijnbouw, Jahrg. 56, part 2, p. 84, pl. 12, fig. 14.

The trivial name is a homonym of *C. ornatum* Winchell and Marcy (1865) and of *C. ornatum* Cleland (1911). The writer tried to reach Dr. Hamlet in 1939 and then wrote to her teacher, Dr. F. Broili. Dr. Broili reports[2] that the whereabouts of Dr. Hamlet

[1] Personal communication, January 9, 1940.
[2] Personal communication, February 21, 1940.

(Frau Dr. Moos) have been unknown to him for some time and gives his permission to replace the homonym. The holotype specimen is imperfectly preserved and little can be learned from the illustrations. The presence of radial ribs and the configuration of the specimen suggest a pectinoid rather than *Conocardium*. The species occurs in the Permian at Nefotassi, Timor.

CONOCARDIUM LATIFASCIATUM Branson, n. name

Conocardium orientale BRANSON [not Janischewski], *1937*, Jour. Paleontology, vol. 11, p. 657, pl. 89, fig. 23.

The trivial name used by the writer in 1937 is preoccupied by *C. orientale* Janischewski (1900). The species occurs in the Sacajawea formation (Middle Mississippian) in Fremont County, Wyoming.

CONOCARDIUM ISBERGI Branson, n. name

Conocardium pygmaeum ISBERG [not (Hisinger)], *1934*, Studien über Lamellibranchiaten des Leptaenakalkes in Dalarna: Dissertation, Upsala University, Lund, p. 322, pl. 29, figs. 7a–b.

Isberg's name is preoccupied by *Cardium pygmaeum* Hisinger (1837), correctly referred to the genus *Conocardium* by Barrande in 1882. The writer accords no nomenclatorial standing to *C. eboraceum* mutation *pygmaeum* Loomis (1903), who gave the name indiscriminately to most of the dwarfed species of the Tully pyrite bed. Isberg's species occurs in the upper part of the Leptaena limestone (Upper Ordovician) at Kallholn, Dalarna, Sweden.

CONOCARDIUM CONALATUM Branson, n. name

Conocardium cuneatum HALL [not (Roemer)], *1856*, Albany Inst. Trans., vol. 4, p. 14.

Conocardium cuneatum, WHITFIELD, *1882*, Am. Mus. Nat. History Bull., vol. 1, p. 60, pl. 7, figs. 24–26.

Conocardium cuneatum, HALL, *1883*, Indiana Geol. Survey 12th Rept. p. 345, pl. 30, figs. 24–26.

Conocardium cuneatum, CUMINGS and BEEDE, *19*[illegible] Indiana Geol. Survey, 30th Ann. Rept., p. [illegible] pl. 23, figs. 24–26.

Hall's name is preoccupied by *Pleurorhynchus cuneatus* Roemer (1850). *Pleurorhynchus* is a synonym of *Conocardium*, and Roemer referred the species to *Conocardium* in the explanation of his plate 2. *C. conalatum* occurs in the Salem limestone of Washington County, Indiana.

CONOCARDIUM DIGITATUM Branson, n. name

Cardium irregulare DE KONINCK [not Eichwald], *1847*, Soc. sci. Liége Mém, t. 4, p. 89, pl. 4, figs. 14a–b.

Conocardium irregulare, D'ORBIGNY, *1850*, Prodrome de Paléontologie, t. 1, p. 132.

Conocardium irregulare, DE KONINCK, *1885*, Mus. royal histoire nat. Belgique Ann., t. 11, p. 117, pl. 20, figs. 23–25.

Conocardium irregulare, HIND, *1900*, Paleont. Soc., Mon. Brit. Carb. Lamellibranchs, vol. 1, p. 456, pl. 51, figs. 12–13.

De Koninck's trivial name is a homonym

EXPLANATION OF PLATE 59

All illustrations ×3 unless otherwise indicated.

FIGS. *1, 2, 5–8—Conocardium antiquatum* Branson, n. name. *1*, Steinkern of a right valve; Manitoba Mus. Nat. History. *2*, Right valve with shell surface well preserved; Manitoba Mus. Nat. History. *5*, Left valve of an immature specimen; Manitoba Mus. Nat. History. *6*, Posterior view of same specimen as fig. 5. *7*, Holotype, a left valve; U. S. Nat. Mus. 17897. *8*, Anterior view of a specimen retaining the fringe; Manitoba Mus. Nat. Nistory. (p. 389)

3—Conocardium richmondense Foerste. U. S. Nat. Mus. 87041. A late Ordovician species shown for comparison with *C. antiquatum*. (p. 390)

4—Conocardium, n. sp. U. S. Nat. Mus. Locality 434s. A Middle Ordovician species shown for comparison with *C. antiquatum*. (p. 390)

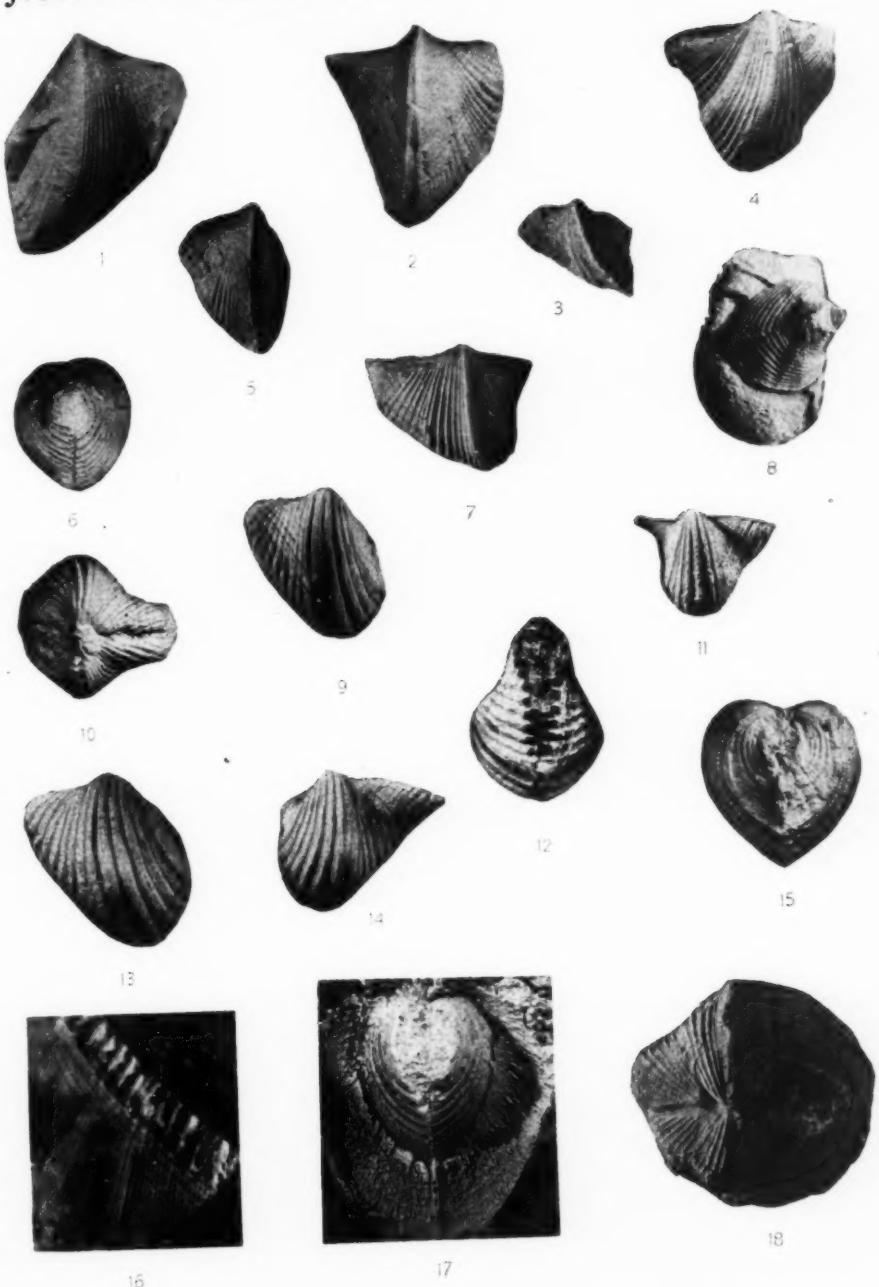
9, 10, 12–15—Conocardium ventricosum Hall. Bielanski Coll. 6528. *9*, A left valve. *10*, Dorsal view of same specimen. *12*, Anteroventral view of denticulated gape. *13*, A left valve. *14*, A right valve. *15*, Posterior view of same specimen as *9* and *10*. (p. 390)

11—Conocardium emmetense Winchell. A specimen from the Traverse beds, Petoskey, Mich., shown for comparison with *C. ventricosum*. (p. 391)

16—Conocardium bohemicum Barrande. U. S. Nat. Mus. View of the carina and fringe, ×10. (p. 390)

17—Conocardium pygmaeum (Hisinger). U. S. Nat. Mus. 98871. A specimen from the Borkholm beds, Esthonia, with fringe well preserved. Posterior view. (p. 388)

18—Conocardium plinthinatum Branson, n. name. U. S. Nat. Mus. Holotype of *C. ornatum* Cleland shown in dorsal view. (p. 387)



Branson, *Conocardium*

of *Cardium irregulare* Eichwald (1830). *C. digitatum* occurs in the Viséan of Belgium.

CONOCARDIUM NEXILE Branson, n. name

Conocardium phillipsi DE KONINCK [not d'Orbigny], *1885*, Mus. royal histoire nat. Belgique Ann., t. 11, p. 114, pl. 19, figs. 5–7.

The name *C. phillipsi* de Koninck is preoccupied by *C. phillipsi* d'Orbigny (1850), a new name given to *Pleurorhynchus minax* Phillips (1841), Devonian, not *P. minax* Phillips (1836), Lower Carboniferous. Many authors have not recognized the replacement names advanced by d'Orbigny in his Prodrome, but they are entirely legal since he gave definite indications to the specimens to which he referred. For instance, the common North American Onondagan species is properly referred to as *Conocardium subtrigonale* d'Orbigny (1850), which is a replacement name for *Pleurorhynchus trigonalis* Hall (1843), homonym of *Pleurorhynchus trigonalis* Phillips (1836). *Conocardium nexile* occurs in the Tournaisian of Tournai, Belgium.

CONOCARDIUM TOURNAISENSE Branson, n. name

Conocardium antiquum DE KONINCK, *1885*, Mus. Royal histoire nat. Belgique Ann., t. 11, p. 118, pl. 20, figs. 38–40.

De Koninck's name is a still-born homonym of *Lichas antiquus* Steininger (1837), which is a *Conocardium*. The species occurs in the Tournaisian of Tournai, Belgium.

CONOCARDIUM ANTIQUATUM Branson, n. name

Plate 59, figures 1, 2, 5–8

Pleurorhynchus antiquus OWEN [not (Steininger)], *1852*, Report of a geological survey of Wisconsin, Iowa and Minnesota, p. 627, pl. 2B, fig. 19.
Conocardium antiquum, BILLINGS, *1865*, Canada Geol. Survey Paleozoic Fossils, vol. 1, p. 42.
Conocardium antiquum, WHITEAVES, *1897*, Canada Geol. Survey, vol. 3, part 3, p. 187.

Owen's trivial name is preoccupied by *Lichas antiquus* Steininger (1837), the genotype of *Lichas* Steininger, which is a synonym of *Conocardium*. Owen figured the specimen poorly and with but a few words of description in the explanation of the plate. In his table on page 627 he lists it as *Pleurorhynchus* (N. S.?) in the column for Lower Silurian, Utica Slate, and gives the locality as Lower Fort Garry, Red River of the North. Dr. E. Leith[3] of the University of Manitoba places the horizon as Middle or Upper Ordovician and the locality at Garson, Manitoba, about 18 miles north of Winnipeg and about 8 miles from Lower Fort Garry.

Owen's holotype specimen is preserved in the United States National Museum (no. 17,897), where it was studied and photographed by the writer. Four other specimens from the same locality were lent to the writer from a private collection in the Manitoba Museum of Natural History through the kind offices of Dr. Leith. From these specimens an exact description of the species is possible.

The holotype is a left valve from which the outer layer of shell is weathered. A note on the label shows that it was further prepared by Ulrich in 1912. The shell is sharply divided into anterior and posterior portions by a strong carina. The posterior (truncate) end is about half the size of the anterior, the slope is steep and bears nine narrow radial ribs separated by deep grooves equal to the ribs in width, and the two hindmost ribs are wider and flatter than the others. The posterior wing is small, and the tube is weakly developed if present at all. The carina is strong, high, sharp, and is slightly oblique posteriorly. The body of the shell bears six strong rounded ribs, four originating at the beak and three intercalated successively next to the carina. The anterior wing is large and bears 12 low ribs separated by narrow interspaces and is minutely marked by concentric lamellae. The posterior rib of the anterior wing is intercalated. The hinge is straight and corresponds to the greatest length of the shell. The beak is straight and prominent.

The Manitoba specimens show several other features of the species. A right valve is not so deeply weathered as the holotype and exhibits a bifurcate carina closely marked by minute longitudinal ridges. The relative height is much greater than in the holotype. A small specimen of a right valve differs from the holotype in that it has 10 body ribs and is nearly twice as long as high. A steinkern shows the characteristic shorter and more trigonal shape usual for this type

[3] Personal communication, December 29, 1939.

of preservation. One specimen is unusual in that the fragile posterior expansion of the carina is preserved. This is the structure which was called the "fringe" by Hall, "Schleppe" by Halfar, "l'éventail" by Barrande, and "Kragen" by Beushausen. Fischer separated those species with this structure from the other species of *Conocardium* under the name *Rhipidocardium*, with genotype species *Conocardium bohemicum*. With the possible exception of *C. beecheri* Raymond, the oldest species of the genus, the writer knows of no species that does not have a fringe. The fringe in *C. antiquatum* extends from the flat posterior face of the carina in a short curve to a point above the base of the posterior slope and is then straight to its margin opposite the posterior end of the shell. The fringe is composed of longitudinal lamellae vertical to the surface of the valve and curving upward. Each lamella consists of a row of hexagonal prisms with rounded outlines. In this specimen a portion of the outer layer of the shell is preserved, and it is marked by a pattern of minute squares. The eroded surface of the posterior slope bears 15 to 18 radial ribs. The surface of the posterior wing is marked by five longitudinal striations, which are continuous with the concentric markings of the posterior slope. The anterior gape is small, short, and is at the upper end of the anterior margin. In this specimen, the beaks are distinctly curved posteriorly.

The holotype specimen is 9 mm. long and 6 mm. high. The species is similar to *C. limatulum* Bradley from the Kimmswick (Middle Ordovician) of Illinois and Missouri. It is larger, more sharply carinate, and the body of the shell is less gibbous. Kindle and Breger compared their *C. oweni* with it on the basis of Owen's figure, but the writer sees little similarity. *C. richmondense* Foerste has a markedly oblique carina and a single large posterior rib. *C. immaturum* Billings from the Leray limestone in Quebec was said by Billings to differ from *C. antiquatum* in that the ventral margin of the body projects farther ventrally than that of the anterior. The writer is unable to make a comparison upon the basis of the meager description and inadequate illustration of that species. Billing's idealized drawing recalls certain Carboniferous species rather than Ordovician ones. An undescribed species from the Ordovician "Holston limestone" of Saltville, Virginia has a wider body, more nearly central carina, and unlike ornamentation.

CONOCARDIUM VENTRICOSUM Hall
Plate 59, figures 9, 10, 12–15

Conocardium ventricosum HALL, *1860*, New York State Cabinet Nat. History 13th Ann. Rept., p. 91.

Conocardium altum, KEYES, *1888*, Acad. Nat. Sci. Philadelphia Proc., vol. 40, p. 247, pl. 12, figs. 4a–b.

Conocardium altum KEYES, *1892*, Iowa Acad. Sci. Proc., vol. 1, pp. 23, 24.

As was shown in an earlier part of this paper, Hall's trivial name preoccupies *C. ventricosum* Tolmachoff. Dr. Tolmachoff considers that Hall's name is a nomen nudum, but kindly supplied a new name for his species "in respect to the memory of Dr. Hall." Perhaps unfortunately, the International Rules of Zoological Nomenclature recognize names proposed with even a pretense of description, and Hall gave a reasonably complete analysis of the characters of the species. The writer finds no subsequent reference to the name, but numerous specimens are to be found in collections. *C. altum* Keyes is unquestionably the same species, as can be shown from the description, from comparison of Keyes illustrations with topotypes of *C. ventricosum*, and by the fact that although *Conocardium* is abundant in the Cedar Valley limestone, the type horizon of both species, but one species is present with the exception of rare imperfect specimens of a species of the distinctly different *cuneus* type.

The species is here described and illustrated on the basis of specimens in the Bielanski Collection of the University of Iowa, supplemented by specimens from other collections. The type specimens of neither Hall's nor Keyes' description are at present available.

The shell is wide, almost circular in transverse section at the beaks. The posterior is truncate, its anterior border recessed beneath the carina. The posterior wing is small, with a small, but distinct rostrum ventral to the line of the hinge. The body of the shell is prominent, inflated, with broadly rounded outlines. The anterior wing is inflated above the anterior slope and is

sharply terminated in a 45° angle between the hinge line and the posteroventral margin. The anterior gape is large, circular in anterior outline, denticulated along its margins and strongly so in the posterior part. The hinge is straight; the beaks rounded, elevated, slightly curved posteriorly.

The ornamentation of the shell is distinctive. The writer has found that shell ornament in specimens of *Conocardium* varies with depth of weathering of the shell. He believes that in all unweathered shells the surface is smooth, but that nearly all specimens are eroded, and in this condition they exhibit radial ribs, which in life were completely concealed by an outer shell layer of prismatic cellular calcium carbonate like that of the fringe. Parts of the shell surface of some specimens of *C. ventricosum* are essentially intact and are smooth, or in some cases show the minute reticulation governed by the pattern of prisms. The shell substance is particularly thick in the ventral part of the body of the shell. In an eroded shell the body bears six broad ribs separated by narrow interspaces. The surface of each body rib is striated, the central ones by three striae. The surface is made nodose by the crossing of concentric lamellae of equal prominence to the striae. The carina, which bears the fringe, is far to the posterior side of the center of the valve and overhangs the abrupt posterior slope. The posterior slope bears six wide flat ribs separated by narrow interspaces. Two of these originate at the beak, the others are intercalated at the carina. The anterior wing bears 10 even ribs with interspaces of equal width; the anterior ribs of the wing are trifid.

The interior of the anterior wing bears strong internal ribs, the ventral ends of which form the denticulations of the anterior gape. The upper pair of internal ribs are rolled inward and upward to form a pair of cones with apices near the beaks. This type of internal structure is characteristic of most species of *Conocardium* and will be further discussed in a later paper.

C. ventricosum is one of a large group of similar species characteristic of Middle and Upper Devonian rocks. Barrande described no less than 22 species and varieties from the Devonian of Bohemia, and 40 have been described from the Devonian of other parts of Germany and of France. The species is nearest to *C. emmetense* Winchell from the Traverse group of Michigan. In that species the body is narrower, the posterior slope is narrower and is less abruptly truncate, and the rostrum is longer. *C. tripartitum* Pohl is a similar species.

A large specimen is 9 mm. long, 10 mm. high, and 9.5 mm. thick. The description given here is from specimens No. 6528 in the Bielanski Collection at the University of Iowa, which were collected from Bielanski's *Pentamerella laevis* zonule of the Garrison substage of the Cedar Valley limestone from near Iowa City, Iowa. Other specimens in this collection are Nos. 6829, 6707, 6832, 6864, 6722, 6496, and 6713 from various levels in the Davenport, Coralville, and Garrison substages of the Cedar Valley limestone. The writer studied five specimens in the Calvin Collection of the University of Iowa, from Pine Creek, Muscatine County, Iowa; no. 1804 in the White Collection of the University of Michigan; no. 45199 in the Gurley Collection of the University of Chicago; and five specimens from the base of the Coralville in Johnson County, Iowa, from the collection of Tulsa University.

OTHER NAMES

Cardium propinquum Muenster (1837), referred to *Conocardium* by D'Orbigny (1850), appears to be a valid name, as it has page preference over *Cardium propinquum* Muenster (1837), a Cretaceous species.

Cardium paucicostatum Muenster (1840) is a still-born homonym of *Cardium paucicostatum* Deshayes (1838). The species was referred to *Conocardium* by d'Orbigny in 1850, but Clarke considers that it is probably a *Honeoyea*.

Cardium semialatum Muenster (1840) is a still-born homonym of *Cardium semialatum* Andrzejevski (1832). The species was referred to *Conocardium* by d'Orbigny in 1850 and to *Honeoyea* by Clarke in 1904.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 3, PP. 393–396, PL. 60, MAY 1942

A NEW OPHIURAN FROM THE EOCENE OF NEW JERSEY

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ABSTRACT—*Ophiomusium stephensoni*, n. sp., is described from disarticulated plates from the Vincentown sand of New Jersey.

THE OPHIURAN plates discussed in this paper were picked from a small quantity of Vincentown sand collected many years ago from Vincentown, New Jersey, probably from the marl pit on the farm then belonging to Dr. Haines.

The Rancocas group in New Jersey is divided into the Vincentown sand, above, and the Hornerstown marl, below. Previous to 1928 the Rancocas group and its two members were referred to the Upper Cretaceous. This correlation, based upon the work of W. B. Clark, was later modified by G. N. Knapp and H. B. Kümmel (1904). However, in 1927, C. W. Cooke and L. W. Stephenson (1928) visited a number of these Upper Cretaceous outcrops in New Jersey and came to the conclusion that the Rancocas group is of Eocene age. This conclusion is based upon the stratigraphic relations and an analysis of the fauna. But the work of F. Canu and R. S. Bassler (1933) on the Bryozoa from the Vincentown sand does not confirm this correlation. Instead they are inclined to favor the older classification, which puts the Vincentown sand in the Upper Cretaceous.

The Vincentown sand is divided into two facies: a calcareous facies and a glauconite-quartz-sand facies. It is in the calcareous part that most of the fossils are found. These fossils consist of Bryozoa, Foraminifera, echinoids, corals and "other calcareous remains" (Mansfield, 1922). Included in the term "other calcareous remains" are the 1026 small disarticulated ophiuran plates with which this paper deals. These plates are of the following kinds and quantities:

Radial shield	90
Interradial marginal plate	65
Dorsal arm plate	41
Jaw	3
Lateral arm plate	631
Ventral arm plate	41
Vertebral ossicle	155
Total	1026

It can be seen from these figures that the number of ventral and dorsal arm plates is the same. However, the number of lateral arm plates, which should be twice that of the ventral or dorsal, is nearly 16 times as great. One explanation for this fact is that the ventral and dorsal arm plates are smaller and more fragile and were lost or broken in washing the material. The other is that some ophiurans have well-developed dorsal and ventral arm plates only in the region of the disk. The distal portion of the arm is devoid of them. The number of vertebral ossicles should be very close to that of the ventral and dorsal arm plates, if these plates are present throughout the arm; but instead they are three and three-quarters times more common. The interradial marginal plates—one of the larger variety—of which there are only five to each specimen, assuming there were five arms, are way out of proportion to all the rest. The radial shields, of which there are only two for each arm, are about in proportion to the interradial marginal plates. The jaws, which are also large plates, are far below the usual number, since there should be 10 in each animal. The absence of disk plates can be explained by the fact that many ophiurans have the power to shed their arms when necessary and later to regrow them. This would tend to give a greater number of arm plates in the sediments. Another explanation which appears to be more plausible is that when these animals die their disks break up first and the plates become more widely scattered than the arm plates, which are more closely united. This has been exemplified in other instances where the arms have remained intact while the disk has been totally destroyed.

That this Eocene ophiuran was one in which the disk was made up of heavy, thick plates is shown by the radial shields, the jaws and especially the interradial marginal plates. The interradial marginal plates are

of particular importance in the allocation of the form. Moreover, the lateral arm plates belong to a form with very stiff, rigid arms, and the dorsal and ventral arm plates are not so numerous—perhaps because they were absent from the distal part of the arm. Moreover, the general shape of the interradial marginal plates and the lateral arm plates indicates generic characters that are found in one living genus, *Ophiomusium*.

H. L. Clark (1915) embraced in the genus *Ophiomusium* some 36 species, of which 20 were confined to the Pacific Ocean and 15 to the Atlantic, while one species was common to both oceans. Since then, R. Koehler (1922) has added eight more species to the Pacific group. The bathometric range of this genus is from about 40 fathoms down to over 2000 fathoms, but the greatest number of species come from depths of 200 fathoms or more. Only seven species have been recorded from the continental shelf. Thus it is safe to say that *Ophiomusium* is a deep-water form.

Only two Eocene species of Ophiuroidae have heretofore been described—*Ophiuretes eocaenus* from Belgium and *Ophiura wetherelli* from England. In addition to these, the writer has assigned several ophiuran plates from the Eocene of Venezuela to *Ophiura* sp. This is a very small representation of the class in comparison with the 18 known species from the Cretaceous and the approximately 1400 living species. Undoubtedly many more species lived during the Eocene, for many of the recent genera have representatives as far back as the Cretaceous. Some unidentified ophiurans in Eocene material now await description. The species described in the present paper, the first Eocene ophiuran from North America, increases the number of known Eocene species in the world to four and the Tertiary species to 12.

The genus *Ophiomusium* is one of the oldest known. It extends back to the Carboniferous—*O. calathospongum* from the Mississippian of Pennsylvania. The next younger species of this genus is *O. ferrugineum*, from the Dogger (Jurassic) of Switzerland. The new Eocene species helps to fill in the gap from the Jurassic to Recent times.

None of the recent species of *Ophiomusium* agree in detail with the fossil form, and therefore it is necessary to create a new species. The specific name *stephensoni* has been chosen in honor of Dr. L. W. Stephenson.

SYSTEMATIC DESCRIPTION

Order CHILOPHIURIDA
Family OPHIOLEPIDIDAE
Genus OPHIOMUSIUM Lyman
OPHIOMUSIUM STEPHENSONI
C. Berry, n. sp.
Plate 60, figures 1–24

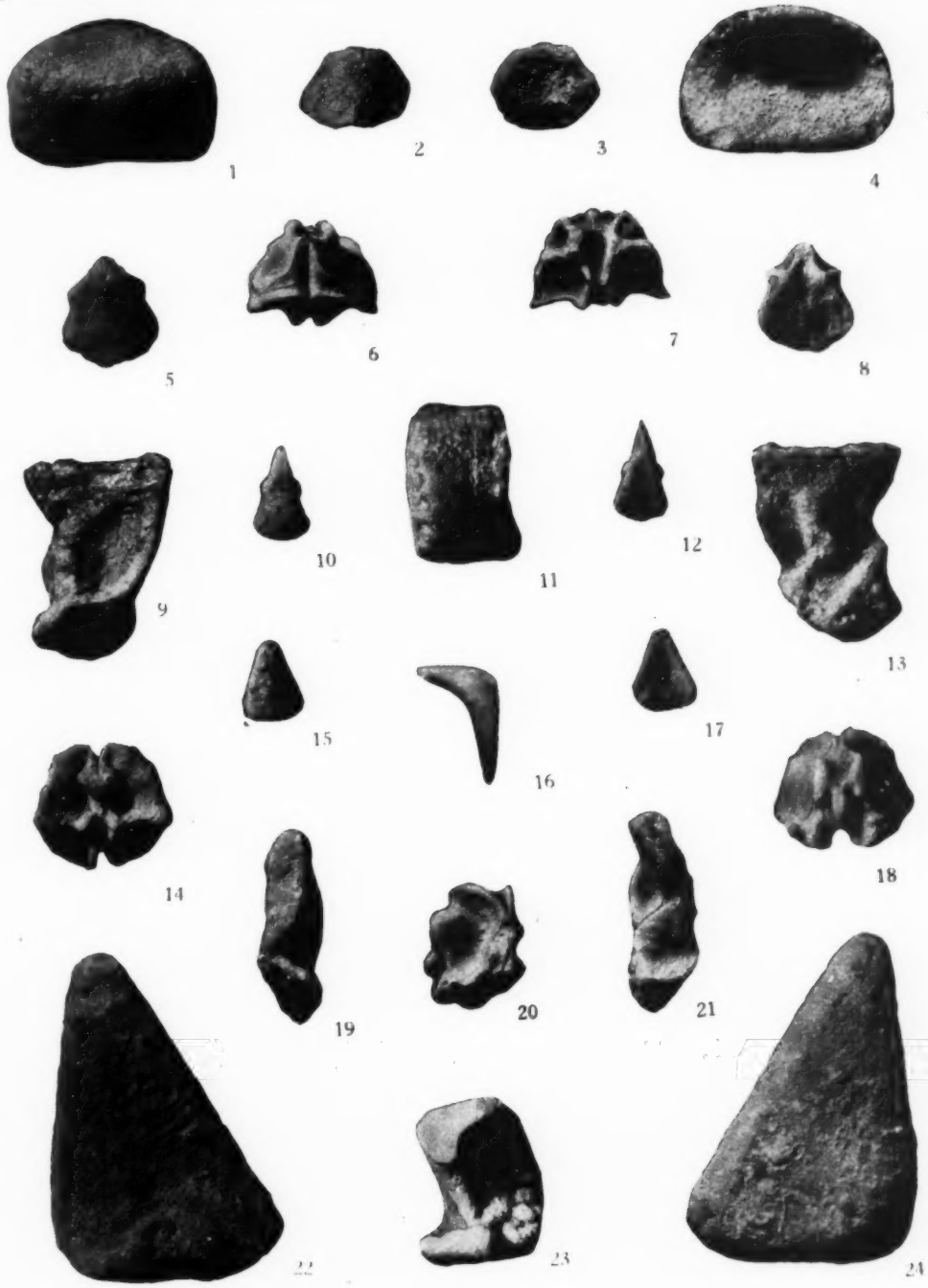
Radial shield (left).—Outline a scalene triangle, angles rounded, inner and aboral sides form angle of 90°. Plate slightly arched transverse to its long axis. Dorsal surface (pl. 60, fig. 24) flat, with beveled margins, inner one steeper than the rest. Ventral surface (pl. 60, fig. 22) flat except for two slightly raised condyles situated at right angles and in the center margin. Plate thickest here. Length 4.12 mm., width 2.88 mm.

Interradial marginal plates.—Outside surface (pl. 60, fig. 1) highly arched along shorter axis, forming an angle of nearly 90°. Lateral margins convex, rounding into an acute dorsal margin. Ventral margin straight. Inside surface (pl. 60, fig. 4) highly concave, conforming with that of the outside; edges rounded. Longest axis, 2.59 mm.; shorter axis in straight line, 1.53 mm. Thickness 0.41 mm. The angularity of this plate indicates that the edge of the disk was not rounded.

Dorsal arm plate.—Outline a truncated triangle, line of truncation forming adoral margin, which is undulating. Aboral margin strongly convex, lateral margin straight or slightly concave. External surface (dorsal)

EXPLANATION OF PLATE 60

FIGS. *1–24—Ophiomusium stephensoni* C. Berry, n. sp., ×11. *1, 4, 16,* Outside, inside, and end surfaces of interradial marginal plate. *2, 3, 15, 17,* Dorsal and ventral surfaces of dorsal arm plate. *5, 8, 10, 12,* Ventral and dorsal surfaces of ventral arm plate. *6, 7, 14, 18, 20,* Dorsal, ventral, adoral, aboral, and lateral surfaces of vertebral ossicle. *9, 13, 19, 21,* Inside, outside, ventral, and dorsal surfaces of jaw. *11, 23,* Outside and inside surfaces of lateral arm plate. *22, 24,* Ventral and dorsal surfaces of radial shield.



Ophiomusium stephensoni C. Berry

(pl. 60, fig. 2) smooth, strongly arched transversely to axis of plate. Internal surface (ventral) (pl. 60, fig. 3) smooth, concave conforming with external surface. Smaller specimen (pl. 60, figs. 15, 17) similar but much narrower in proportion to its length. The location of both of these plates is comparable to those of the ventral arm plates. One of the characteristics of this genus is the reduction in size of the dorsal and ventral arm plates or their complete absence in the arm distad to the disk. Largest specimen's length is 1.00 mm.; greatest width, 1.35 mm.

Jaw.—Dorsal surface (pl. 60, fig. 21): Outline rectangular, surface uneven, aboral portion rounding down to outside margin; a high ridge at aboral end. Adoral portion consisting of high narrow crest. Separating these two regions is a deep U-shaped groove, in which the circumoesophageal nerve ring is located.

Inside surface (pl. 60, fig. 9): Outline of plate a modified rectangle, adoral margin straight, aboral margin convex, rounding into ventral margin. Aboral and dorsal margins forming an angle. Dorsal margin irregular and bisinuate. Ventral margin straight. Surface uneven, with oval depression in center of plate bounded by broad rounded ridge along dorsal margin. Diagonal view of articulating surface of jaw consisting of irregular ridges and grooves in aboral portion of plate, which cross the plate in an irregular line. Just adoral of center is the suture line between the adoral and aboral portions of the plate.

Ventral surface (pl. 60, fig. 19): Outline same as in reverse view. Surface consisting of narrow flat ridge with steep sides.

Outside surface (pl. 60, fig. 13): Outline same as in reverse view. The surface of the plate is irregular, covered with ridges and depressions. In the center portion of the plate there is a short vertical-sided ridge, which runs diagonally across the plate. Adoral of this ridge the surface is even, sloping away from adoral margin. Aboral of the ridge there is a U-shaped groove, which crosses the plate from the ventral margin to the dorsal in a curving adoral direction, cutting the dorsal margin at an angle and forming the U-shaped groove for the circumeosophageal nerve ring. The aboral portion of the plate is irregularly pitted.

Aboral surface is too indefinite to either describe or figure.

This jaw plate described is the right half and is 2.41 mm. long, 1.88 mm. high, and 0.88 mm. thick at maximum measurements.

Lateral arm plate.—Shape of plate varies with location on the arm. This plate (right) is located about midway of the arm. Outline rectangular, corners rounded. Outside surface (pl. 60, fig. 11) smooth, arched transversely to long axis of plate. Surface slopes towards aboral margin, which is a series of five small unequally rounded condyles. Inside surface (pl. 60, fig. 23) uneven, with flattened portion paralleling ventral margin. Larger irregular flattened surface adjoining dorsal margin, the ventral lobe of which fits down into hollow of vertebral ossicle. Both flattened areas are on same plane, the region between these areas is in general concave. The aboral and adoral margins accumulate in a diagonal ridge a little adoral of the center of plate. Ridge runs from near aboral ventral corner towards adoral-dorsal corner. Paralleling aboral margin and adjacent to it are five slightly raised oval areas. Height 2.00 mm., greatest width 1.30 mm.

Ventral arm plate.—Outline triangular, apex adoral, aboral margin strongly convex. Lateral margins strongly bisinuate, the two sinuses equal in size. External (ventral) surface (pl. 60, fig. 5) smooth, arched transversely to long axis of plate. Internal (dorsal) surface (pl. 60, fig. 8) uneven. Aboral portion of plate beveled at a low angle by a surface which originates as a shallow depression near adoral apex but widens and deepens aborally. Lateral margins beveled in adoral part; bisinuate. Length, 1.35 mm.; width at aboral margin, 1.18 mm. This plate is located on the adoral part of the arm, while plate 60, figures 10, 12, is located very near the extremity of the arm. Plate triangular, proportion of width to height about 1 to 2. Lateral margins bisinuate, aboral margin convex, adoral end sharply pointed. External (ventral) surface smooth. Aboral part of internal surface beveled, adoral part flat. Lateral sides vertical, bisinuate. Length 1.12 mm. width at aboral margin 0.71 mm.

Vertebral ossicle.—Adoral surface (pl. 60, fig. 14): Outline a modified rectangle, lower canal furrow indents surface to greater degree than upper canal furrow. Dorsal margin

of ala forms rounded arch. Surface of ala flat, with raised cordate centrally located zygapophysis. Two sharp-pointed condyles separated by deep oval pit flank the zygapophysis on the ventral side.

Aboral surface (pl. 60, fig. 18): Outline same as in reverse view. Surface very uneven, center occupied by highly elevated articulating area, consisting of zygosphene and zygocondyles, the former just dorsal of lower canal furrow, while the latter are located one on each side of the dorsal portion of the zygosphene. Both the zygosphene and zygocondyles have vertical sides and are about three times as long as wide. The zygocondyles are separated in dorsal portion by a deep cordate depression. These condyles converge slightly towards the dorsal end. The dorsal portion of the plate consists of the parapophyses, whose lateral margins are broken off. The ventral portion of the plate is occupied by the anterior hypapophyses.

Lateral surface (pl. 60, fig. 20): Outline a modified rectangle whose surface is very uneven. Adoral margin straight; aboral margin occupied by zygocondyles and zygosphene, the latter protruding slightly further aborally than the former. The parapophysis, which is concave, occupies the greater portion of the surface.

Dorsal surface (pl. 60, fig. 6): Outline irregular. Adoral margin straight, except for centrally located zygapophysis. Center of aboral margin occupied by zygosphene flanked by zygocondyles, which in turn are flanked by anterior hypapophyses. Surface irregular, crossed adoral-aborally by V-shaped upper canal furrow. The parapophyses slope aborally towards ventral side. The region between the zygocondyles forms a semi-spherical depression.

Ventral surface (pl. 60, fig. 7): Outline same as in reverse view. Surface very uneven, center crossed adoral-aborally by lower canal furrow, the aboral end of which is broader and deeper than the other end. The posterior hypapophysis cuts the plate as a high ridge running parallel to adoral margin of plate. The adoral portion is much more deeply depressed than the aboral portion.

The location of this plate in the arm is somewhere just aboral of the disk. The farther from the disk, the greater becomes the saddle on the dorsal side between the adoral and aboral ends. Since there is no such saddle in the described plate, one can conclude that its location is near the disk. The type plate is 1.18 mm. from base of each canal furrow on the adoral side, 1.24 mm. long, and 1.71 mm. across the face of the ala at greatest dimension.

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JOURNAL OF PALEONTOLOGY, VOL. 16, NO. 3, PP. 397–398, 1 TEXT FIG., MAY 1942

BIOLOGICAL EVIDENCE AS TO THE RATE AT WHICH TESTS OF FORAMINIFERA ARE CONTRIBUTED TO MARINE SEDIMENTS

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IN THE VAST and growing literature on the Foraminifera virtually nothing is to be found concerning the life span, rate of growth, rate of reproduction, density of populations on the floor of the sea or the rate at which the tests of these marine Protozoa are contributed to the sediments. We selected *Elphidium crispum* Linn. (*Polystomella crispa*) for this discussion because the classic work of Lister (1895), and the universal distribution of this species in shallow water make it the most widely recognized of the Foraminifera. This is fortunate, since it probably best exemplifies, the group both as to test morphology and the sequence of stages in the life cycle.

The rate of growth in the sexually produced microspheric and the asexually produced megalospheric generations is graphically represented in figure 1. The mean diameter of the tests at intervals of 10 chambers was determined from ground sections, and the mean number of chambers produced, from samples of 1,000 individuals taken monthly for 12 months. It was found that reproduction is largely limited to a few weeks beginning in March, and that the number of chambers in megalospheric and microspheric tests at the end of the first year was 33 and 47 respectively. In the second year the limit of growth for the previous season is marked by a change in the length and width of the chambers, which usually results in a depression in the outer margin of the tests. The maximum growth stage in *E. crispum* is about 80 chambers.

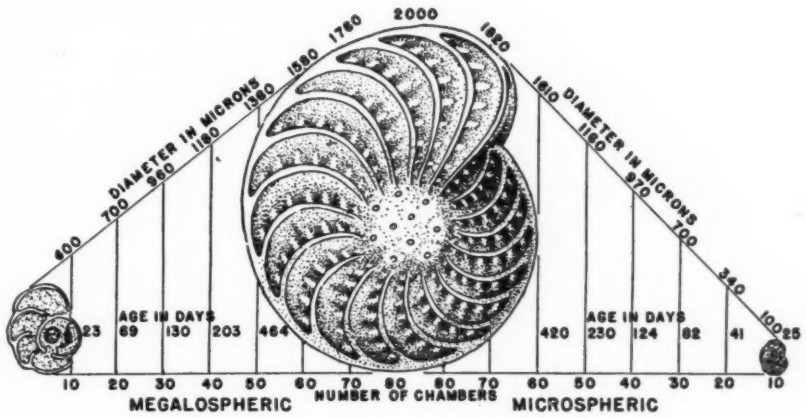

FIG. 1.

The life span is from one to two years. This was evident from the bimodal nature of frequency distribution curves for chamber counts, and cytological evidence of reproduction in individuals having less than the mean number of chambers produced the first year; therefore the life cycle, including a sexual and an asexual phase, requires two, three, or even four years.

The rate of reproduction may be estimated from the number of megalospheric juveniles asexually produced by microspheric individuals maintained in a balanced

[1] Contribution No. 316.

aquarium (which was found to be 152 to 224) and the ratio of microspheric to megalospheric individuals (which averaged about 1 to 37). From these data it was calculated that the annual productivity of *E. crispum* is about forty-fold.

The population per unit area on the floor of the sea was found by counting the number of protoplasmic casts in measured samples of surface sediment after the samples had been treated with formalin and the tests dissolved in acidified alcohol. Populations greater than 1,200 per sq. ft. were observed, and *E. crispum* was only one of many species in the samples. These samples were taken with a special suction grab that removes a definite unit area of surface sediments at depths ranging from 10 to 200 meters.

The rate at which the tests of *E. crispum* are contributed to the sediments may be estimated from the density of populations at the beginning of the reproductive season, the rate of reproduction, and the rate of mortality of the early juvenile stages, since the larger tests are especially resistant to erosion and were not noticeably affected by having passed through the digestive tract of bottom-feeding invertebrates. From these data it would seem probable that not less than 1,000 tests of *E. crispum* per square foot are contributed annually to the sediments at several of the stations worked.

The rate of sedimentation could be estimated from the rate at which tests are contributed to the sediments, and the number of tests in samples taken with a tubular sampler. However in areas in which *E. crispum* are numerous this would have little significance because turbulence and currents at these shallow depths result in much reworking of the sediments.

Much of the data referred to is included in a paper titled "The correlation of ecological data with observed life activities of the Foraminifera in the sea," which is in an advanced stage of preparation. This work was made possible through a John Simon Guggenheim Foundation Fellowship.

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AN ATHERINID FISH FROM THE PLIOCENE OF OKLAHOMA

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ABSTRACT—The fossil fish described by Stovall and McAnulty (1939) as *Plancterus kansae?*, from beds of presumed Pliocene age in Oklahoma, are not referable to that genus nor to the family Cyprinodontidae (order Cyprinodontes), but rather to the family Atherinidae (suborder Percesoces, order Percomorphi). The fossil imprints closely resemble the Recent Mississippian species *Menidia audens* and are tentatively identified as *Menidia* sp.

FOSSIL fishes of late Tertiary and Quaternary age are of concern not only to the paleontologist but also to the ichthyologist. This is particularly true of Pliocene and Pleistocene fresh-water fishes, for a critical study of their remains will undoubtedly bear significantly on the study of the taxonomy, distribution and speciation of the Recent species. In turn the paleontological picture will be enhanced by a comparison of the fossils with the better-known extant fishes.

Since I have held this view and have long specialized in studies of the fishes of the order Cyprinodontes, I was much interested in the recent paper on "Cyprinodontidae from the Pliocene in Roger Mills County, Oklahoma" (Stovall and McAnulty, 1939).

An examination of the published figures showed that the fish described was incorrectly identified as "*Plancterus kansae?*."[1] Contrary to the statement of Stovall and McAnulty, the deeply forked caudal fin virtually precludes any such identification. A truncate or rounded caudal fin characterizes not only the genus *Plancterus*, but also all other American members of the family Cyprinodontidae and the order Cyprinodontes. A lunate caudal fin is a feature of two peculiar groups, the Adrianichthyidae of Celebes and the Lamprichthyinae of Lake Tanganyika, and lobate caudals are developed in certain African Fundulinae and in some specimens of *Lebistes*, but no cyprinodont has the regularly forked caudal fin of the fossils under discussion. The identification of the Oklahoma species as a cyprinodont is also inconsistent with the location of the main dorsal fin well behind the origin of the long, low anal, and with the sharp snout and other features.

Since the impression given was that of an atherine fish (family Atherinidae, suborder Percesoces, order Percomorphi), the figures were compared in detail with a dissected specimen of *Menidia audens* Hay (with the exception of the beaked *Labidesthes sicculus*, this is the only living representative of the family in the Mississippi River basin). The agreement with the *Menidia* was very close. The caudal fins are similar in shape. The anal and main dorsal fins seem to be alike in position, form and basal length. The anal fin in the fossil appears from the illustrations to have extended much farther back than the count of "14?" rays would indicate. A trace seems to have persisted of other, more posterior rays, which would be expected to occur in a fish of the *Menidia* type, but which, on account of their shortness and their investment in a scaly sheath, would not be expected to have preserved well in fossilization. The first dorsal fin, which in the atherines is well in advance of the second dorsal and comprises a cluster of a few weak spines, appears to be faintly exhibited, above the front of the anal fin, in Stovall and McAnulty's figure 2. The paired fins, so far as obvious, also seem to agree. The number of vertebrae in the specimen of *Menidia* examined, 19+20=39, is about identical with the number shown in each of the two illustrations. The assigned vertebral count of 28 to 30 (p. 750) is certainly too low; that of 24 to 40 (p. 751), far too variable. The form

[1] The status of this common Great Plains cyprinodont is treated by Hubbs (1926, p. 15).

of the head, back, and muzzle, rather well shown in the imprints, is essentially like that of *Menidia audens*.

The reconstructed habitat—a series of small lakes, a larger and deeper lake, or the protected backwaters of a stream with rapidly shelving bottoms—would well fit *Menidia audens* or another atherinid.

The fossil in question obviously has little in common with *Zanteclites hubbsi* Jordan and Gilbert, from the Puente diatomaceous shales (Miocene) of southern California. It lacks the primitive features ascribed to that form (Jordan and Hubbs, 1919, pp. 10–12, pl. 11, fig. 40). There is no apparent reason for distinguishing the Oklahoma fish from the sub-family Atherinopsinae, which embraces most of the living New-World Atherinidae (Jordan and Hubbs, 1919, pp. 14, 48–49). The body appears to have been a little more robust, and the first dorsal fin possibly a little farther back than in *Menidia audens* and most other forms of that genus, but there are no sure grounds for generic separation. There has been no opportunity to reexamine the fossils nor to compare them with the skeletons of several Recent species. Tentatively, therefore, it is suggested that the specimens be referred to as *Menidia* sp.

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BUCKMAN, S. S. Died Feb. 26, 1929.
CANU, FERDINAND. Died Feb. 12, 1932.
COBBOLD, EDGAR STERLING. Died Nov. 20, 1936.
DEPÉRET, PROF. CHARLES. Died May 17, 1939.
KAIER, PROF. JOHAN. Died Oct. 31, 1931.
KOKEN, E. Died Nov. 24, 1912.
KOLIHA, DR. JAN. Died April 7, 1939.
NATHORST, DR. A. C. Died Jan. 20, 1921.
POMPECKI, DR. J. F. Died July 8, 1930.
STEFANINI, PROF. G. Died Sept. 15, 1938.
WOODWARD, DR. H. Died Sept. 6, 1921.

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*BARRELL, JOSEPH. Died May 4, 1919.
*BEEDE, JOSHUA W. Died. Feb. 27, 1940.
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*BENSLEY, B. A. Died Jan. 20, 1934.
*BILLINGS, W. R. Died Mar. 1, 1920.
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